STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

GEOLOGY OF SOUTHWESTERN SANTA BARBARA COUNTY CALIFORNIA

POINT ARGUELLO, LOMPOC, POINT CONCEPTION, LOS OLIVOS, AND GAVIOTA QUADRANGLES

BULLETIN 150
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DIVISION OF MINES
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STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO
OLAF P. JENKINS, Chief

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GEOLOGY OF SOUTHWESTERN SANTA BARBARA COUNTY CALIFORNIA

POINT ARGUELLO, LOMPOC, POINT CONCEPTION, LOS OLIVOS, AND GAVIOTA QUADRANGLES

By
T. W DIBBLEE, JR.

Aerial view toward the northwest, showing Santa Ynez Mountains and coast line at Tajiguas, Santa Barbara County. *Photo by Santa Barbara Chamber of Commerce*

LETTER OF TRANSMITTAL

To His Excellency
The Honorable Earl Warren
Governor of the State of California

Sir:

I have the honor to transmit herewith Bulletin 150, *Geology of Southwestern Santa Barbara County, California,* prepared under the direction of Olaf P. Jenkins, Chief of the Division of Mines, Department of Natural Resources. The report covers an area topographically mapped by the Federal Government in five 15-minute quadrangles comprising an area of 700 square miles, namely: Point Arguello, Lompoc, Point Conception, Los Olivos, and Gaviota quadrangles. In this report the geology of the area is described in great detail and graphically shown on colored lithograph maps which are accompanied by stratigraphic, structural, and physiographic diagrams. The economic minerals of the area are also described and mapped. These include oil and gas, asphalt, diatomite, limestone, bentonite, flagstone, road gravel, manganese ore, and ground water. The report describes three important oil fields—Capitan, Lompoc, and Zaca, as well as the world's largest diatomite quarries.

The author of this comprehensive report, T. W. Dibblee Jr., spent some 20 years studying the region, partly as a private venture in research, and partly in the employ of two major oil companies. Acknowledgment is made by Mr. Dibblee to these companies, namely, the Union Oil Company and the Richfield Oil Corporation, for their generosity in permitting the material to be made available to the public through the auspices of the State Division of Mines.

Respectfully submitted,

WARREN T. HANNUM, Director
Department of Natural Resources

December 1, 1949

CONTENTS

ILLUSTRATIONS

GEOLOGY OF
SOUTHWESTERN SANTA BARBARA COUNTY, CALIFORNIA
(Point Arguello, Lompoc, Point Conception, Los Olivos, and Gaviota Quadrangles)

By T. W. Dibblee Jr.*

ABSTRACT

The Point Arguello, Lompoc, Los Olivos, Point Conception, and Gaviota quadrangles comprise the southwestern quarter of Santa Barbara County, and cover the western Santa Ynez Mountains, southern portion of Santa Maria Basin, and a small portion of the San Rafael Mountains.

The Santa Ynez Mountains are composed of two topographic parts: the higher Santa Ynez Range on the southeast, and the lower Santa Ynez Mountains on the northwest. The Santa Maria Basin is made up on the south of the lowlands of Burton Mesa, Lompoc Valley and Santa Ynez Valley, which are traversed by the westward-flowing Santa Ynez River; and on the north of the Purisima Hills and San Rafael foothills, in part separated by Los Alamos Valley. The region is in the mature stage of the erosion cycle. Remnants of an earlier cycle, which reached late maturity, are locally preserved.

The area mapped is composed of two stratigraphic provinces, the Santa Ynez Mountains on the south and the Santa Maria Basin on the north. The Franciscan formation (Upper Jurassic ?), a series of sedimentary and volcanic rocks with numerous serpentinized intrusions, is the basement formation of both provinces. The Espada formation (Upper Jurassic and Lower Cretaceous) is well developed in the Santa Ynez Mountains and may locally underlie the Santa Maria Basin. In the Santa Ynez Mountains this formation is overlain by a very thick series of predominantly marine Upper Cretaceous, Eocene, Oligocene, and lower Miocene clastic sediments. With the exception of the lower Miocene, these are absent in the Santa Maria Basin. Marine siliceous sediments of the Monterey and Sisquoc formations (middle Miocene through lower Pliocene) are common to both areas but become extremely thick in the Santa Maria Basin. The former locally contains some volcanic rocks at the base in the Santa Ynez Mountains. The Sisquoc in the Santa Maria Basin is overlain by the marine Foxen shale and Careaga sand (upper Pliocene) and the terrestrial Paso Robles and Orcutt formations (Plio-Pleistocene).

The Santa Ynez Mountains and Santa Maria Basin are separate structural provinces. The Santa Ynez Mountains are made up of two structural units: the southern portion is a south-dipping homocline in a very thick stratigraphic section uplifted on the north along the Santa Ynez fault zone, and the northern portion is an anticlinorum composed of numerous folds developed in a thinning stratigraphic section with many unconformities. In the Santa Maria Basin the Burton Mesa-Lompoc Valley-lower Santa Ynez Valley portion is a structurally rigid wedge-shaped area of Franciscan rocks covered by a thin Tertiary-Quaternary section only slightly deformed. The structure of Los Alamos and upper Santa Ynez Valleys is a synclinal trough developed in an extremely thick Tertiary-Quaternary section, which is flanked by the anticlinal Purisima Hills and San Rafael foothills. The San Rafael Mountains within Los Olivos quadrangle are a mass of Franciscan rocks thrust southwestward toward the San Rafael foothills.

Formations of the Santa Ynez Mountains were deposited in the Santa Barbara embayment which underwent sedimentation from Cretaceous to Pliocene time. The Santa Maria Basin developed during Miocene time and received sediments throughout the Pliocene and Pleistocene. Tectonic history indicates that the structures within the area are the result of a recurrent stress system active as far back as Oligocene, and possibly even early Eocene or Cretaceous time, but most intense in Pliocene and Pleistocene time.

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* Geologist, Richfield Oil Corporation. Manuscript submitted for publication January 1949.

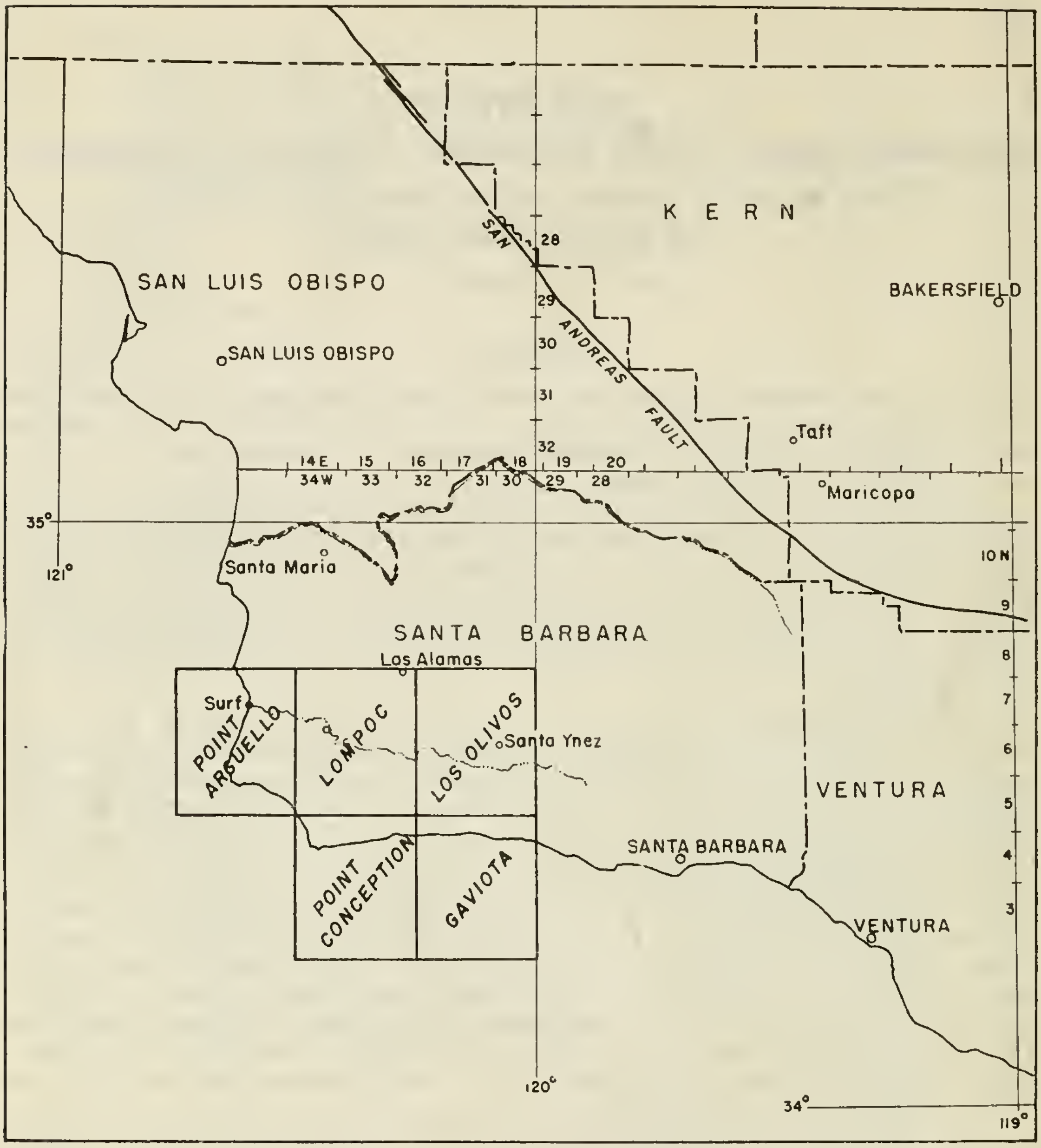

FIGURE 1. Index map showing location of Point Arguello, Lompoc, Point Conception, Los Olivos, and Gaviota quadrangles, southwestern Santa Barbara County.

Petroleum is the most important economic resource of the mapped area, which contains three highly productive oil fields. Capitan field on the south coast produces light oil and some gas. Lompoc and Zaca fields in the Santa Maria Basin produce medium and heavy oil. Deposits of tar sand occur in the Purisima Hills but none have been worked commercially.

The northwestern Santa Ynez Mountains contain large deposits of high-grade diatomite. The Johns-Manville quarries south of Lompoc are the largest diatomite quarries in the world. Limestone deposits occur in the Miocene of the northwestern Santa Ynez Mountains, but have been quarried only for road gravel. Sand, gravel, and cherty shale are also quarried for road material.

INTRODUCTION

The southwestern portion of Santa Barbara County is an area of Franciscan basement overlain by a sequence of predominantly marine sedimentary formations and one local volcanic formation. The area is made up of parts of two geologic provinces roughly separated by the westward-flowing Santa Ynez River.

The Santa Ynez Mountains lie south of the river and trend eastward parallel to the Santa Barbara Channel on the south. The Franciscan in this range is overlain by a nearly continuous series of predominantly marine sedimentary formations ranging in age from uppermost Jurassic to Pliocene. These formations are very thick and conformable on the south flank, but thin rapidly to the north, where there are several unconformities. Structurally the high southern portion of this range is a south-dipping homocline uplifted on the north along the Santa Ynez fault system, while the lower northern portion is largely an area of folding.

The lowland area north of the river takes in the southern portion of the Santa Maria Basin, which within the area mapped comprises the Lompoc Valley, Santa Ynez Valley, Burton Mesa, Purisima Hills, and parts of Los Alamos Valley and San Rafael foothills. The stratigraphic section of this basin consists of marine Miocene and Pliocene and terrestrial Pleistocene which becomes very thick along the Los Alamos synclinal trough. The Burton Mesa, Purisima Hills, and San Rafael foothills are anticlinal areas; the intervening valleys are synclinal.

The small portion of the San Rafael Mountains mapped is a block of Franciscan rocks thrust southwest toward the Santa Maria Basin.

ACKNOWLEDGMENTS

For permission to publish the geologic maps and this report, the writer is deeply indebted to Union Oil Company of California, and to Richfield Oil Corporation. The writer is also indebted to R. K. Cross, for the portion of the area mapped by him; to M. L. Natland and W. T. Rothwell, for assistance rendered in microfaunal determinations; to A. W. Hughes, and to T. W. Dibblee and C. E. Russel, manager and foreman, respectively, of Rancho San Julian, for their cooperation and for use of the ranch house as headquarters while carrying on the work; and to the owners and superintendents of the various ranches throughout the area.

HISTORY

The Early Explorers

The Santa Barbara coastal area was first explored by Cabrillo and Ferrelo in two small ships, in October 1542. After exploring the south coast and the islands they encountered such stormy weather where the coast "veered northward" (Pt. Conception) that they were forced to remain several days in the channel before resuming their journey. They spent several days at or near Refugio (Refuge) Beach, where they were met by friendly Indians who offered fresh sardines and other food.

The earliest land expedition was led by Gaspar de Portolá, accompanied by Padre Junipero Serra and his ardent Franciscan monks, in 1767, who took possession of Alta California in the name of the King of Spain. In traversing what is now Santa Barbara County the party traveled up the coast. Along the channel coast the native Indians were so friendly as to offer an abundance of seeds, acorns and fresh fish, in return for beads and other trinkets, and even begged the travelers to remain with them and share their huts.

This same route was followed by the expedition of Juan Bautista de Anza in 1774 and 1775.

Spanish explorers and mission padres were very much impressed by the beautiful region that is now Santa Barbara County, which bears striking resemblance to their mother country. They found a brush-covered mountain ridge (Santa Ynez Range) sloping southward to grassy foothills bordering the sea, and northward to rolling foothills and fertile valleys covered with luxuriant grasses and scattered groves of oak. The climate was ideal the year round. The area offered great possibilities as grazing land for cattle and sheep. As the Spanish "conquistadores" entered this land during the 18th century the primitive life of the native Indians gave way to the gay and colorful "hacienda" era that centered in the great ranches and Franciscan missions. The Spanish crown rewarded the soldier-explorers with large grants of land, known as "ranchos," and the padres received large tracts on which to establish their missions.

The Missions

Mission Santa Barbara, founded in 1786, was the first of the three missions established by the Franciscan padres (fathers) in what is now Santa Barbara County to convert the native Indians to Christians and into useful subjects. The other two missions were established in the Santa Ynez River valley.

In the lower portion of the valley Mission La Purisima Concepcion was founded December 8, 1787, by Padre Lasuen, presidente of the Franciscan missionaries and successor to Padre Junipero Serra. This was the eleventh of the 21 missions established in California; it was erected near the present site of the Veterans Memorial Building at Lompoc. The mission served the growing community of Indian neophytes until the earthquake of 1812 which almost completely destroyed it. It then became known as La Mision Vieja de la Purisima. In 1816 the mission was rebuilt at a new site at the mouth of Purisima Canyon, and was served by Franciscan friars until confiscated and sold by Mexican politicians in 1845. It was then abandoned and became a ruin, but was restored after 1933 by the federal government and made into a state park and museum.

In the upper portion of Santa Ynez River valley, Mission Santa Ines was founded at its present site at Solvang on September 17, 1804, by Padre Estavan Tapis, as the nineteenth mission established. The church and buildings were completed in 1812. The earthquake of that year damaged it, and the present church was completed in 1817. The mission was served by the Franciscan friars and was the site of the first seminary (priesthood) college in California, established in 1844. The mission was confiscated after the Mexican revolution, but is now a parish church in charge of the Capuchin Franciscans.

The Ranchos

The historic background of southwestern Santa Barbara County centers in the great ranchos into which it was divided. These large tracts of land granted to the Spanish soldier-explorers in commendation of their services, are shown on the old topographic maps of Lompoc and Guadalupe quadrangles (scale 1 inch = 2 miles), issued by the U. S. Geological Survey in 1905.

At each rancho the grantee built at or near a large spring an hacienda, a long, low house of adobe walls 2 or 3 feet thick, with a long front porch. Most of the houses were shaded by trees or grape arbors. Helping hands occupied smaller outbuildings. The ranchos were stocked with herds of Spanish cattle, which roamed at large, there being no fences. In the spring of each year rodeos (roundups) were held, during which the cattle were herded together, calves branded and steers sold. In addition, large numbers of sheep were raised on some ranchos. Although periodic droughts caused the loss of much livestock, the rancheros prospered from the sale of beef, hides, tallow, mutton, and wool while California was under the Spanish and Mexican flags, although much of the business was with Yankee traders from Boston and New York. Aside from the working of cattle and sheep there was little to do, so that the life of the Californians took on a gay fiesta spirit.

When American explorers and troops invaded California during the Gold Rush era of the late forties, the rancheros offered no resistance, as they prospered from business with Yankee traders, and resented being taxed to the limit by greedy Mexican politicians. Being good Catholics, the rancheros likewise resisted confiscation of the missions. In 1846 General John C. Frémont and his Yankee troops came south by way of Foxen Canyon and over San Marcos Pass, and took Santa Barbara without resistance.

After California was annexed to the United States in 1850, the "gringos" (Yankees) settled in Santa Barbara County in ever increasing numbers, intermarried with the Spanish-Californians, and, since they were more ambitious and energetic, gradually acquired lands of the ranchos from the descendants of the grantees. As the ranchos became divided and subdivided into smaller and smaller tracts, fences were erected, and the valleys were cultivated. The semi-wild, long-horned Spanish cattle were gradually replaced by the large chunky "white-face" Herefords as the main source of beef, and by docile Holstein and Guernsey cows as the source of dairy products.

One of the most colorful of the Spanish ranchos is Rancho San Julian, whose history is in general typical of that of the other ranchos in the area. In 1817 the Company of the Presidio of Santa Barbara established Rancho San Julian as a source of meat supply for the soldiers of the King of Spain, and it was then known as Rancho Nacional. At that time the first section of the present adobe house was built and served as headquarters. In commendation for his many military services several ranchos were granted by the Spanish Crown to Capitan Jose Antonio de la Guerra y Noriega, who was born in Novales, Spain, in 1779, from a long line of distinguished ancestors. He came to California in 1800 and was stationed at Santa Barbara in 1806 where he served for 24 years as commandante of the Presidio and was commissioned "Habilitado General" (Resident General) of both Californias. In 1837 he became grantee of Rancho San Julian, comprising 11 leagues or 48,000 acres. In addition he was granted Rancho Los Alamos in Los Alamos Valley area, and Ranchos Simi, Tapo, and El Conejo in what is now Ventura County.

Upon the death of Don Jose Antonio de la Guerra y Noriega, Rancho San Julian was inherited by his sons, one of whom was Pablo de la Guerra, and it later passed into the ownership of Don Gaspar Oreña, their brother-in-law married to Maria Antonia de la Guerra.

In 1867 Thos. Bloodgood Dibblee and his brother, Albert Dibblee, came to California from New York and purchased Rancho San Julian from Gaspar Oreña and his wife, and a year later T. B. Dibblee married Francisca de la Guerra, daughter of Pablo de la Guerra. T. B. Dibblee stocked the rancho with one of the finest herds of registered shorthorn beef cattle known which for many years produced top grade foundation stock.

Soon after the Dibblee brothers acquired Rancho San Julian they formed a partnership with W. W. Hollister and purchased the adjoining Ranchos Espada, Lompoc, Mission Vieja de la Purisima, Cañada de Salsipuedes, Las Cruces, and Nuestra Señora del Refugio. These vast, unfenced rangelands, totaling some 150,000 acres, were managed by T. B. Dibblee, and the San Julian ranch house (Casa de San Julian) was headquarters. The lands were stocked with both cattle and sheep.

For the springtime rodeos, the vaqueros rode out many miles from Casa de San Julian to gather the cattle of each local area into corrals conveniently located. They were joined and assisted by vaqueros from neighboring ranchos in order to identify their respective cattle. After the cattle were gathered in, the calves were branded, and steers in good condition and any other cattle to be sold were separated out and driven to headquarters for sale. At nightfall the vaqueros often camped and ate barbecued steak under the oak trees. The rodeos lasted several weeks, often several days being required to work each local area. After the cattle brought in to headquarters were sold, they were driven to Gaviota Beach and loaded on board ship at a loading pier, built by T. B. Dibblee, and shipped to San Francisco, the main market. After the Pacific Railroad was built from that city south to Guadalupe, in Santa Maria Valley, in the nineties, the cattle were sometimes driven 30 miles to that station (it took 4 days) and shipped north by rail.

The lands of Dibblee and Hollister were at one time stocked with more than 50,000 head of sheep besides the cattle. This large herd consisted of many flocks each herded by a lonely shepherd, usually a Spanish-Basque, and his faithful dogs. He spent his lifetime in the hills with his flock, and was supplied each two weeks with provisions from headquarters. Several times a year he brought his flock in to headquarters to be sheared, dipped, and doctored, and to wean the lambs, and have the yearling wethers separated to be shipped north to market. Sometimes these were driven all the way to San Francisco, fed on the way, and sold.

In the seventies the Dibblee-Hollister partnership was dissolved and the lands and livestock divided. Ranchos Espada, Lompoc, and Mission Vieja de la Purisima were sold. Ranchos Cañada de Salsipuedes, Las Cruces, and Nuestra Señora del Refugio went to W. W. Hollister and were inherited by his son, James J. Hollister, present owner. The western portion of Rancho San Julian went to A. Dibblee and was sold years later. The eastern portion of Rancho San Julian was retained by T. B. Dibblee and his wife, Francisca de la Guerra, and upon their death was inherited by their seven children, one of whom is T. Wilson Dibblee who succeeds his father as manager.

Rancho San Julian enjoys the distinction of being one of the few remaining California ranchos owned by the descendants of its grantee. Still used as headquarters is the original adobe "hacienda" with two-foot-thick walls, of which the west wing was built by the Spanish soldiers in 1817, the central portion by Captain Jose Antonio de la Guerra in 1837, and the east wing by T. B. Dibblee about 1875.

Lompoc Valley

Rancho Lompoc, which included the wild, verdant valley now called Lompoc, was purchased by a determined group of California Yankees in 1874 who foresaw its tremendous agricultural possibilities. They set aside a corner of the rancho as a townsite and in 1875 founded the town of Lompoc. They advertised the valley's potential greatness throughout America and soon farmers, dairymen, tradesmen, and professional men from every section arrived. They built up the town of Lompoc to a thriving little city of 6,500.

Lompoc Valley is one of the most intensively and successfully farmed areas in the nation. Almost all of its rich alluvial soil is under irrigation and more than 50 varieties of vegetables and herbs are produced on a year-round basis, which yield an annual income to Lompoc running into millions of dollars.

Lompoc Valley is most famous for its acres of flowers. More than 500 varieties of flowers are grown commercially for seed on over 2,500 acres of the valley floor, which in spring and summer make a floral display as colorful as can be imagined. Ideal climatic and soil conditions enable Lompoc Valley to produce a wide variety of flower seed with a high germination rate.

Rancho Jesus Maria, which covers the sandy, windswept Burton Mesa, was acquired by the U. S. Army during the last war and built into one of California's largest military installations. The reservation covers 96,000 acres and was activated during the war. The Army plans to use it as a training ground for the peacetime military force.

Santa Ynez Valley

Upper Santa Ynez Valley has always been a grazing area as it is too arid and rolling for year-round farming. In late years much of it has been dry-farmed for grain and barley. A famous artesian spring issues from the southern portion, of which the water was used by native Indians who inhabited the vicinity until recent years. The water was also used by the Franciscan friars to irrigate fields near Mission Santa Ines. Adjacent to this big spring is the pueblo of Santa Ynez, the oldest in Santa Ynez Valley, from which the valley derives its name. The pueblo consisted of a large wooden hotel, garage, and store, and served as a stopover for the stages going to and from Santa Barbara over San Marcos Pass. The old hotel burned down about 1935 and the pueblo never grew.

The village of Los Olivos is built around famous "Mattei's Tavern", which used to serve as a stopover for stage-coaches traveling between Santa Barbara and San Francisco. The lower portion of Santa Ynez Valley has been developed into a small but intensively farmed area, largely by immigrants from Denmark who settled there. About 1910 a group of Danes established near the Santa Ines mission a townsite which they named "Solvang" (Sunny Valley). It is now a thriving community inhabited by several hundred Danes. Three miles down, the highway village of Buellton was centered around Andersen's Inn, home of "split pea soup."

GEOGRAPHIC FEATURES

Location and Method of Work. The area mapped comprises the southwestern portion of Santa Barbara County, which lies about midway between Santa Barbara and Santa Maria. The area totals about 700 square miles.

The base maps used for plotting the areal geology are five 15-minute topographic quadrangles, scale 1:62500, namely Point Arguello, Lompoc, Los Olivos, Point Conception, and Gaviota. These were issued in 1941 by the U. S. Army Corps of Engineers.

Areal geology was mapped in 1929 and 1930, then from 1936 to 1939, in detail, on aerial photographs (approximate scales, 1:20000 and 1:24000). This geology was later transferred to the 15-minute topographic quadrangles. Minor details have necessarily been omitted because of the much smaller scale of the quadrangles. The areal mapping was done by the writer throughout the area with the exception of that portion of the San Rafael foothills lying west of Santa Agueda-Lisque Canyons in northern Los Olivos quadrangle, which was mapped by R. K. Cross, but checked in the field by the writer. The geology of the Purisima Hills was taken from U. S. Geological Survey Oil & Gas Investigations Preliminary Map 14, with slight modifications by the writer.

Accessibility and Transportation. With the exception of the higher part of the Santa Ynez Range, all points within the area lie within 2 miles of roads. The main coastal highway, U. S. 101, runs from Santa Barbara, 18 miles east of Capitan, to Santa Maria, 18 miles northwest of Los Alamos. Towns within the area are all connected by good paved roads. Throughout the area are many secondary roads, both county and private. The Southern Pacific railroad follows the coast throughout the area.

Population and Industry. Four towns lie along the course of the Santa Ynez River. Lompoc (population 6500) is the largest and most westerly. Camp Cooke is located 10 miles northwest, and Mission La Purisima Concepcion 3 miles northeast of Lompoc. Farther east along the river are Buellton (population 300), Solvang (400), site of Mission Santa Ines, and Santa Ynez (250). Other small towns are Los Olivos (250) and Los Alamos (300).

The fertile lands of Los Alamos, Lompoc, and lower Santa Ynez Valleys are extensively cultivated for alfalfa and truck-gardening. They are irrigated from numerous wells. Upper Santa Ynez Valley is largely dry-farmed. The luxuriant grasslands of the rolling hills throughout the area are devoted to pasturing of beef and dairy cattle.

Land Divisions. With the exception of the United States National Forest land in the San Rafael and higher Santa Ynez Mountains, which is sectionized, practically all of western Santa Barbara County is covered by original Spanish land grants. Only very small areas not covered by the grants are sectionized. These land grants and sections are shown only on the Guadalupe and old Lompoc quadrangles, scale 1:125,000, issued by the U. S. Geological Survey in 1943.

Climate. The climate of southwestern Santa Barbara County is equitable and mild throughout the year, and semi-arid. Summers are kept cool by low marine fog at night, and by the prevailing northwest sea breeze during the day. Winters are mild, but night temperatures often fall below freezing in inland valleys.

Precipitation is in the form of rainfall and may occur any time from October to May, but in most years heavy rains come only during the winter months. Annual rainfall averages about 15 inches throughout the area except in the Santa Ynez and San Rafael Mountains, where it averages about 25 inches.

Exposures and Vegetation. Exposures throughout the area mapped are determined by (1) the character of the underlying formation, and (2) ruggedness of the terrain. The most prominent exposures occur in mountainous areas underlain by hard, resistant rocks, and the poorest in low, rolling hills underlain by soft, easily weathered sediments. The area contains several types of natural vegetation whose distribution is determined by the following factors: (1) the character of the underlying formation; (2) amount of residual soil; (3) steepness of slope; and (4) local climate. In general, steep rocky slopes are covered by brush, and gentle slopes with a heavy soil mantle by grasses and annual herbs.

The high rugged portion of the Santa Ynez Range east of Gaviota Canyon contains the best exposures in the area mapped. Tilted sandstone beds form prominent ledges, especially on the south slope. Shales are less prominently exposed, but have very little soil cover. Regardless of the underlying formation, this entire range is covered with a very dense impregnable chaparral-type brush, composed mainly of lilac, scrub oak, and other shrubs.

In the lower portion of the Santa Ynez Range exposures are good on the rugged south slope west of Gaviota Canyon, but elsewhere are less prominent. Throughout this area brush, either the heavy chaparral type or low sage brush, grows only on hard, resistant formations such as sandstone, conglomerate, hard shales, and volcanic rocks. Clay shale formations and softer shales of the Monterey readily weather into a heavy adobe soil which supports only grasses and annual herbs. Hard formations which fracture readily, such as Monterey cherty shale, are for the most part covered by live oak timber. Since the various types of vegetation are influenced by the underlying formations, their distribution is a great aid in mapping.

The Purisima Hills are more or less covered with soil, but there are good local exposures. The vegetation is a mixture of three types, namely grasses and annual herbs, low brush, and live oak timber. The underlying formations have only slight influence on the distribution of these three types. In general, steep slopes are covered by brush, fractured shale areas by timber, and gentle slopes with deep soil, by grasses. In the western Purisima Hills north of Lompoc oil field is a very dense stand of scrub pine growing on Sisquoc diatomite.

The low rolling San Rafael foothills are made up of loosely consolidated gravels and clays of the Paso Robles formation and are covered with a thick soil mantle. Consequently there are few exposures. This is an area of grasslands, dotted with oaks. The same type of vegetation prevails in the San Rafael Mountains, but with the addition of scattered digger pines.

PREVIOUS LITERATURE

The earliest geological investigation in southwestern Santa Barbara County was made by Thomas Antisell,[1] who accompanied a party of engineers sent by the United States War Department to explore a route for a transcontinental railroad in 1856.

The first geologic map and report published on the area were issued in 1907, after Arnold and Anderson mapped the geology of the Guadalupe and old Lompoc quadrangles on the scale of 1 : 125,000.[2] This reconnaissance work covered all of the quadrangles except a part of the Santa Ynez Mountains. In 1925 the southwestern portion of the adjoining Santa Ynez quadrangle was mapped by R. Nelson.[3]

The geology of the western Santa Ynez Mountains was described briefly by Reed [4] and by Reed and Hollister.[5]

In 1943 Kelley [6] mapped and described in detail the Eocene section of Santa Anita Canyon area.

No detailed information was published on the Santa Maria Basin until 1943, when the U. S. Geological Survey studied and mapped the stratigraphy of that area,[7] and also of the southeastern Purisima, Santa Rita, and Santa Rosa Hills.[8] The Survey has just completed a detailed study and map of the ground-water resources of Lompoc and Santa Ynez Valleys.[9]

The Vaqueros fauna has been discussed by Loel and Corey [10]; that of the Oligocene and Eocene by Arnold and Anderson,[11] Woodring,[12] and Schenck and Kleinpell.[13]

Geology of the Lompoc and Capitan oil fields has been described in California State Division of Mines Bulletin 118.[14]

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[1] Antisell, Thomas, Geological report: Pacific Railroad Survey, vol. 7, pt. 2, chap. 10, pp. 65-74, Washington, D. C., 1856.

[2] Arnold, R., and Anderson, R., Geology and oil resources of Santa Maria oil district, Santa Barbara County, Calif.: U. S. Geol. Survey Bull. 322, pp. 1-161, 1907.

[3] Nelson, R. N., Geology of the hydrographic basin of the upper Santa Ynez River, Calif.: Univ. California Dept. Geol. Sci. Bull., vol. 15, no. 10, pp. 327-396, 1925.

[4] Reed, Ralph D., Geology of California, 355 pp., Tulsa, Oklahoma, Am. Assoc. Petroleum Geologists, 1933.

[5] Reed, Ralph D., and Hollister, J. S., Structural evolution of southern California, pp. 86-97, Tulsa, Oklahoma, Am. Assoc. Petroleum Geologists, 1936.

[6] Kelley, F. R., Eocene stratigraphy in western Santa Ynez Mountains, Santa Barbara County, California: Am. Assoc. Petroleum Geologists Bull., vol. 27, no. 1, pp. 1-19, 1943.

[7] Woodring, W. P., and others, Stratigraphy and paleontology of the Santa Maria district, California: Am. Assoc. Petroleum Geologists Bull., vol. 27, no. 10, pp. 1335-1360, 1943. . . . Geologic map of Santa Maria district, Santa Barbara County, Calif., U. S. Geol. Survey Oil and Gas Inv., Prelim. Map 14 (in 6 sheets), 1944.

[8] Woodring, W. P., and others, Geology of Santa Rosa Hills—eastern Purisima Hills district, Santa Barbara County, California: U. S. Geol. Survey Oil and Gas Inv., Prelim. Map 26, 1945.

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GEOMORPHOLOGY

Physiographic Features

The various physiographic features referred to within the quadrangles mapped, and the principal streams to which reference is made, are shown on plate *7B*. Details of topography and drainage are shown on the topographic quadrangles.

Santa Ynez Mountains. The Santa Ynez Range is one of the eastward-trending Transverse Ranges of southern California. It extends farther west than the other Transverse Ranges, paralleling the Santa Barbara channel on the south and extending continuously from Point Arguello eastward some 75 miles to Matilija Canyon in Ventura County. Only the western portion of the range is within the quadrangles mapped, where it is composed of two parts, the higher Santa Ynez Range, and the lower Santa Ynez Mountains.

Referred to as the "higher Santa Ynez Range" is the prominent mountain ridge extending eastward, unbroken from Gaviota Canyon beyond the area mapped into Ventura County. This mountain range was formed as a block uplifted along the Santa Ynez fault at its northern base. The course of this fault zone is marked by short rift canyons, saddles, or a sharp break in slope. South of the fault the range rises abruptly, forming a bold escarpment, to an even crest line averaging about 2500 feet elevation within Los Olivos quadrangle, but rising higher to the east. South of this crest the range slopes gently seaward. As the range is sculptured out of sedimentary formations dipping south, the crest is essentially a strike ridge; the north flank is characterized by step-like topography and the south flank by dip-slopes. The drainage system is regular. Canyons on the north flank are short and steep, but on the south flank they are long, and the streams have reached grade and have developed small flood plains.

The area referred to as the "lower Santa Ynez Mountains" comprises the hills lying between the "higher Santa Ynez Range" and the Santa Ynez Valley, and extending westward to Point Arguello. The southern crest of these hills averages about 1400 feet elevation and extends from Las Cruces due west to the south side of Jalama Canyon. It is cut through by Santa Anita Canyon. This ridge is topographically and geologically the westward extension of the higher Santa Ynez Range, being similar in every respect, but on a smaller scale. From the head of Jalama Canyon another ridge branches off from the southern ridge and extends north of west through a high mass of hills to the prominent ridge of Tranquillon Mountain, which forms the main divide and backbone of the extreme western Santa Ynez Mountains. The drainage system is somewhat irregular because of complex geology. The Santa Rosa Hills average about 1600 feet elevation and form the northern crest of the lower Santa Ynez Mountains. This ridge extends from Salsipuedes Creek eastward to Nojoqui Creek. The hills extending westward and eastward from the Santa Rosa Hills are cut through by several major northward trending canyons antecedent to them. The Santa Rita Hills are geologically part of the Santa Rosa Hills but are separated by the Santa Ynez River which forms an antecedent canyon between them.

San Rafael Mountains. The San Rafael Mountains average about 4000 feet elevation and form the most southerly of the northwest-trending Coast Ranges. Only a very small portion of the southwest flank lies within

Los Olivos quadrangle. The slope is steep, and as it is made up of serpentine and Franciscan rocks, it is characterized by numerous landslides. The range has been thrust up along the Little Pine fault, which is marked by an abrupt change in slope between the mountains on the upthrown side and the San Rafael foothills to the southwest.

San Rafael Foothills. Referred to as the San Rafael foothills is the broad area of low rolling hills southwest of the San Rafael Mountains. They are the result of gentle anticlinal uplift, and since they are made up of soft formations they are characterized by low, rounded ridges of more or less equal height, and canyons which have reached grade. These hills are cut through by the major canyons, antecedent to them, draining southwestward from the San Rafael Mountains.

Purisima Hills. The Purisima Hills are an anticlinal uplift. Their main crest averages about 1500 feet elevation, and trends about N. 75° W. They extend into the Santa Maria quadrangle on the northwest where they merge into Burton Mesa on the west. The crest is located about midway between the northern base and the southern base except in the western portion, where it approaches the latter. The hills are of moderate relief. The drainage pattern is normal for an area of anticlinal uplift, with consequent canyons cut down each flank. The streams have reached grade and have developed small flood plains. The southeast end of the Purisima Hills is cut through by the antecedent canyon of Zaca Creek.

Santa Ynez Valley. The Santa Ynez Valley is a synclinal area which has undergone little or no uplift. It is separated by the southeast end of the Purisima Hills just north of Solvang into an upper or northeastern portion, and a lower or southwestern portion.

The upper Santa Ynez Valley is a broad, roughly triangular valley with an average elevation of 700 feet. It is essentially a structural trough, but the southern portion has been formed by lateral stream erosion. Streams do not follow this valley but drain southward across it into the Santa Ynez River at its southern edge. Some of these have cut below the original valley surface, indicating slight uplift. The river has cut several terraces and a small flood plain down to an elevation of some 500 feet. Geologically the upper Santa Ynez Valley is a synclinal trough extending through Los Olivos northwestward through a gap between the Purisima Hills and San Rafael foothills into Los Alamos Valley.

The lower Santa Ynez Valley averages about 350 feet elevation and is a synclinal trough between the eastern Purisima Hills and the Santa Ynez Mountains. This portion is followed by the Santa Ynez River which has destroyed the original valley surface and formed a flood plain. About 6 miles west of Buellton the river leaves this valley and cuts south between the Santa Rosa and Santa Rita Hills; but the synclinal trough continues westward through Santa Rita Valley, where the original depositional surface has been elevated and warped, but is still preserved locally. The Santa Rita Valley is at an elevation of about 600 feet and is separated by low saddles from Santa Ynez and Lompoc Valleys.

Lompoc Valley. Lompoc Valley is geologically the westward extension of the lower Santa Ynez Valley synclinal trough, but is considerably broader. It has undergone slight uplift and erosion, so that the original sandy surface has been broadly warped and preserved only in the northeastern and southwestern portions, at an average elevation of

300 feet. The Santa Ynez River has cut through this sandy valley and has formed a flood plain, referred to as ''Lompoc Plain'' by Upson,[15] about 2 miles wide and about 11 miles long at an elevation of less than 100 feet.

Burton Mesa. To the northwest, Lompoc Valley blends into a low mesa-like area known as Burton Mesa, which averages about 400 feet in elevation. This is an uplifted peneplain locally dissected by youthful canyons.

Coastal Terraces. At least three wave-cut terraces are developed along the coast. The lowest occurs throughout the coast at an elevation of 50 to 150 feet. It forms a broad but much dissected coastal plain north and east of Point Conception, and also near Point Arguello. A higher terrace, at an elevation of about 200 feet, is well developed against Burton Mesa, but is preserved only as small remnants elsewhere. Isolated remnants of a still higher terrace occur at an elevation of about 500 feet on the seaward slopes of the hills northeast of Point Conception and Point Arguello, and also near Alegria and Refugio Canyons.

Drainage

The drainage systems within each physiographic province have been described. With the exception of the north flank of the Purisima Hills which drains into Los Alamos Valley, the entire area north of the crest of the Santa Ynez Mountains is drained by the Santa Ynez River system. All tributaries gather into this river which flows west into the ocean at Surf. The river generally follows the Santa Ynez-Lompoc Valley synclinal trough, but in many places cuts south of it into the foothills of the Santa Ynez Mountains. The general drainage system is shown on plate 7*B*.

During heavy rainy seasons the Santa Ynez River carries considerable runoff. The river generally runs throughout the year, but drys up locally during prolonged dry seasons. Other streams are intermittent, but some of the major streams in the Santa Ynez Mountains run throughout the year.

Springs are abundant in the Santa Ynez and San Rafael Mountains; some occur in the Purisima Hills, and a few in the San Rafael foothills. The valleys are generally devoid of springs except for a very large artesian spring at Santa Ynez.

Erosion Cycles

Southwestern Santa Barbara County has been through at least two cycles of erosion during the Pleistocene. The first cycle occurred during middle Pleistocene time prior to deposition of the middle or upper Pleistocene Orcutt sand; the second took place during late Pleistocene.

During the first cycle, Burton Mesa, Santa Rita Hills, and the hills north of Cañada Honda were peneplained; the lower Santa Ynez Mountains, Purisima Hills, and San Rafael foothills were probably reduced to late maturity or an old-age stage of erosion. This erosion surface is preserved in the western and southeastern Purisima Hills, but elsewhere there are only small remnants. Hills which once occupied the vicinity of Solvang and Santa Ynez were peneplained to form the southern part of upper Santa Ynez Valley. This erosion period was followed by filling of Lompoc, Santa Ynez, and Los Alamos Valleys by sand of the Orcutt formation and terrestrial gravels.

[15] Op. cit.

The second cycle was inaugurated by renewed uplift of the entire region by compressive forces. The mountains and hills were uplifted to their present heights, thereby causing a renewed downcutting of canyons by streams. The peneplained surface of Burton Mesa and the hills north of Cañada Honda were elevated at this time, and were partly dissected by youthful streams. Lompoc and Santa Ynez Valleys were likewise raised but to a lesser amount than the adjacent highlands, and the Santa Ynez River deepened its channel. Regional uplift during the second cycle was recurrent in three or four stages, as indicated by that many terraces along the Santa Ynez River valley, and also by at least three wave-cut terraces along the coast.

The final stage of the second cycle, at the close of Pleistocene or beginning of Recent time, was marked by lateral erosion by streams to form flood-plains in their respective valleys or canyons. During this stage the Santa Ynez River developed the flood-plain of lower Santa Ynez Valley, and the broad, level plain of Lompoc Valley. The level portion of Los Alamos Valley was also formed by lateral stream erosion. As, or after, these flood-plains were formed the flat lower valleys became filled with terrestrial alluvium. This was followed, or possibly accompanied, by regional subsidence, or rise of sea level, of about 300 feet maximum, which caused the lower parts of the alluviated flood-plains to be submerged below sea level; but they were not drowned, as deposition of alluvium apparently kept pace with subsidence. However, in higher areas away from the sea most streams are deepening their channels through the alluvium, indicating slight recent uplift of these areas.

The southwestern portion of Santa Barbara County is an excellent example of an area in which all physiographic features are the direct result of uplift by compressive forces active during Quaternary time, a condition general throughout the Coast Ranges of California. In general, the amount of relief is proportional to the amount of uplift. The highest areas, such as the San Rafael and higher Santa Ynez Ranges, have undergone the greatest amount of uplift, having been elevated along major faults. They are in the early mature stage of erosion, being characterized by sharp ridges and V-shaped canyons. The hilly areas, such as the lower Santa Ynez Mountains, Purisima Hills, and San Rafael foothills, have undergone moderate uplift, mainly by compressive folding. They are in the middle to late mature stage of erosion, being characterized by rounded crests and canyons with small flood plains. The valleys are synclinal troughs between the uplifted areas. They have been raised only slightly and have been subjected to comparatively little erosion.

The submerged area adjacent to the Santa Ynez Mountains has undergone relatively little uplift as compared to the land area. This is indicated by the fact that only the youngest formations of the range, namely, the Sisquoc and Monterey formations, crop out along the coast, and generally dip seaward, indicating relative uplift of the land area. The sea is constantly eroding landward, and in the vicinity of Point Arguello and east of Gaviota the waves have cut through the Sisquoc into the more resistant Monterey shale. Point Arguello and Point Conception are essentially anticlinal uplifts exposing resistant Monterey shale, forming points jutting out into the sea to make right-angle bends in the coast line. Aside from these two prominent points, the coast line is fairly straight, indicating that the mature stage of the wave erosion cycle has been reached.

STRATIGRAPHY

Franciscan Formation

The Franciscan formation of Santa Barbara County is typical of that found elsewhere in California, being composed of sandstone, clay shale, radiolarian chert, and basalt, of Upper Jurassic (?) age. It is the oldest formation in the county and forms the so-called "basement" upon which younger formations were laid down.

The Franciscan is widely exposed along the southwest slope of the San Rafael Mountains, of which a small portion was mapped in the northeast corner of Los Olivos quadrangle. An exposure of clay shale mapped as the Honda shale in the extreme western Santa Ynez Mountains may be a member of the Franciscan. Both exposures are intruded by serpentinous rocks. Wells drilled on Burton Mesa and in the Lompoc oil field encountered the Franciscan below the Miocene formations.

In the San Rafael Mountains the various members of the Franciscan strike due east to N. 60° W., and generally dip steeply north. However, the rocks are so highly sheared and brecciated, and injected by numerous masses of serpentine, that the sequence could not be worked out. The Franciscan here is composed of four rock types, sandstone, clay shale, varicolored chert, and basalt.

The sandstone is bluish green when fresh but weathers brown; it is more or less medium grained, arkosic, and is composed of angular grains, mainly of feldspar. It is massive and hard, but closely jointed so that it does not form prominent outcrops. Much of it contains calcite veinlets. It forms poor exposures and is generally the only rock in the Franciscan which supports brush.

The clay shale is dark brownish green to black and is nearly everywhere in a very highly sheared and brecciated condition. As a result it seldom crops out, but instead forms a deep clayey adobe soil which supports grass. It forms numerous landslides.

The varicolored cherts occur as irregular lenses, most of them less than 50 feet thick, composed of individual layers averaging 2 or 3 inches in thickness of maroon red and light green siliceous chert, separated by thin partings of shale. The chert lenses are generally much contorted or locally brecciated. They form rather prominent outcrops.

The so-called "basalt" is a very dense to amygdaloidal extrusive rock. It locally shows pillow structure, indicating that it was extruded under water. The rock is drab green, but weathers brown; it is massive, hard, but not heavy, and is rather closely jointed. It is more or less altered to greenstone, and contains numerous veinlets of calcite. It is the most resistant rock of the Franciscan, as it forms prominent outcrops; large masses form conspicuous knobs.

In the San Rafael Mountains the Franciscan formation is cut by numerous sill-like masses of serpentine. This was intruded as an ultrabasic rock such as peridotite or pyroxenite, then altered to serpentine by hydrothermal action. The peridotite rocks have been more or less completely altered to serpentine; but where the original rock was pyroxenite, many of the crystals of pyroxene are partially preserved. The serpentine is dark green to bluish green and contains numerous shiny slickensided surfaces resulting from expansion during chemical alteration. Much of it is brecciated, and tends to form landslides. These bare, slickensided green exposures of serpentine are generally devoid of vegetation.

In addition to the San Rafael Mountain exposures, there is a large outcrop of serpentine at the head of San Pascual Canyon in the extreme western Santa Ynez Mountains. This exposure is made up largely of serpentinized pyroxenite. Serpentine also occurs in San Lucas and Wons Canyons as small exposures, where it seems to inject shales of the Espada formation.

Honda Formation

The Honda formation consists of several thousand feet of clay shale exposed only in the extreme western Santa Ynez Mountains at Cañada Honda, from 1 mile to 4 miles east of Point Pedernales.

The Honda formation is composed of dark greenish-brown clay shale commonly containing buff-weathering calcareous concretions. It locally contains thin layers of fine-grained sandstone of the same color. The shale is poorly bedded and is everywhere intensely sheared. The Honda shale either overlies or is intruded by serpentinized pyroxenite to the north, and is unconformably overlain by the Espada formation.

A small indeterminate species of *Aucella* was found in the northernmost exposure of Honda shale in San Pascual Canyon. The Honda shale may be equivalent to the type Knoxville, but its highly sheared condition and unconformable relationship with the Espada formation suggests that it may be a shale member of the Franciscan. Since neither could be proved, it is designated by the local name Honda. The type locality is on the north side of Cañada Honda 3 miles east of Point Pedernales.

Espada Formation

The Espada formation is a thick series of dark greenish-brown sandy shales of predominantly Lower Cretaceous age exposed at several areas on the north side of the Santa Ynez Mountains.

The type locality of the Espada formation is designated as the south side of Cañada Honda about 3 miles east of Point Pedernales, where it is well exposed. Other exposures occur in Salsipuedes and El Jaro Canyons, Nojoqui and Alisal Canyons, and in San Lucas and Wons Canyons.

In all exposures the Espada formation is a monotonous series of dark greenish-brown, thin-bedded silty shales and a lesser amount of thin interbeds of hard fine-grained sandstones. Crude rhythmic bedding is general throughout. The Espada formation is characterized by its prevailing dark greenish-brown color in the shales and sandstones alike, and by the abundant black specks of carbonaceous material in parting planes. Locally the Espada contains thin lenses of conglomerate with well-rounded pebbles of black chert.

The Espada formation is well indurated and is well exposed in creek beds. It forms dark-brown exposures in hills which are invariably covered by brush.

Unfortunately no complete section of the Espada formation is exposed at any one locality. At the type locality at Cañada Honda, the base is well exposed. Here it consists of 1 foot to 5 feet of dark brown conglomeratic sandstone resting unconformably on highly sheared clay shale of the Honda formation. This conglomerate is overlain by about 4000 feet of dark greenish-brown shale and thin hard sandstone as described above. The Espada here is unconformably overlain by lower Miocene beds.

In San Lucas and Wons Canyons a maximum thickness of 6800 feet of Espada formation is exposed, but the base of the section is in fault or intrusive contact with serpentine, and the top is unconformably overlain by Eocene and middle Miocene beds. The relationship of the Espada to the Upper Cretaceous Jalama formation is not definitely known, but these are believed to be in contact at only two localities: at the head of Salsipuedes Canyon, where the relationship appears to be an unconformity, and at Nojoqui Canyon, where shales of the Espada formation are in conformable contact with hard sandstones and dark-gray shales believed to be the Jalama formation.

The Espada formation in the Santa Ynez Mountains is generally known as the "Knoxville" formation by geologists who have worked in the region. In San Lucas Canyon *"Aucella" crassicollis* was found in the upper portion. This places at least part of the Espada formation in the Lower Cretaceous, equivalent to the Paskenta formation of Sacramento Valley. *"Aucella" piochii* was found in shales similar to the Espada in the Casmalia Hills and in the San Rafael Mountains. This indicates Upper Jurassic age, equivalent to the type Knoxville at Sacramento Valley. The Espada formation is lithologically and faunally indivisible, but it probably contains strata equivalent to the type Knoxville (Upper Jurassic), type Paskenta (Lower Cretaceous), and possibly the type Horsetown (middle Cretaceous). Because of lack of faunal control, the formation is here designated by the local name Espada.

Jalama Formation

The Jalama formation consists of about 4000 feet of clay shales and sandstones of Upper Cretaceous age overlying the Espada formation and disconformably overlain by the Eocene Anita shale. The Jalama formation is exposed in the Santa Ynez Mountains at Santa Anita and Jalama Canyons, and at the head of Salsipuedes Canyon; in Ytias and Nojoqui Canyons; and on the north flank of the higher Santa Ynez Range between Gaviota Pass and Quiota Canyon.

The type locality of the Jalama formation is designated as the divide between Santa Anita and Bulito Canyons. Here the section is as follows:

Anita shale (middle Eocene)	
Disconformity (?)	
Gray-white to buff, hard, thick-bedded to massive well-sorted fine to locally medium-grained sandstone; minor interbeds of sandy siltstone. Carries *Trigonia*, *Baculites*	300 ft.
Brown-gray massive to poorly bedded highly micaceous siltstone and silty claystone	1000 ft.
Light buff, hard, well-bedded fine-grained sandstone; minor interbedded clay shale; lower 3 feet contains abundant rounded pebbles of porphyritic volcanic rocks and of Franciscan red and green chert. Contains several fossil reefs of *Calva steinyi*, *Trigonia*	200 ft.
Dark-gray well-bedded clay shale with subspheroidal fracture	800 ft.
Light-brown very hard fine-grained sandstone and interbedded clay shale as above	150 ft.
Dark gray-brown well-bedded clay shale, slightly carbonacous	400 ft.
Total thickness of Jalama formation exposed	2850 ft.
Pacifico fault	

The above sequence holds true for the Jalama formation in Jalama Canyon, and also in the higher Santa Ynez Range south of Alisal ranch.

The relationship to the overlying Eocene Anita shale is accordant, with no evidence of erosion. However in the Santa Rosa Hills the Jalama is overlain by the Anita shale and Sierra Blanca limestone with an angular unconformity of about 15°. At the mouth of Ytias Creek an angular unconformity occurs above the Jalama, but Upper Cretaceous Trigonias occur above the unconformity. These beds are in turn conformably overlain by the Matilija sandstone.

At Santa Anita and Jalama Canyons the Jalama formation is highly fossiliferous and has yielded a large fauna. Of these, the following occur abundantly:

Pelecypoda
- Calva steinyi (Hawley) (= Venus steinyi Hawley)
- Glycymeris veatchii var. major Stanton
- Inoceramus sp.
- Mactra ashburnerii Gabb
- Trigonia evansi Meek
- Trigonia gibboniana Meek

Gastrapoda
- Volutaderma cf. gabbi White

Cephalopoda
- Baculites sp.

These forms place the Jalama formation in the Upper Cretaceous, and correlate it with the Panoche formation of San Joaquin Valley and possibly with the Chico formation of Sacramento Valley.

The Eocene-Oligocene Series

The Eocene and lower Oligocene series is exposed only in the Santa Ynez Range and consists of a very thick conformable series of marine sandstones and shales totaling 9000 feet in the higher Santa Ynez Range eastward from Gaviota Canyon, 6000 feet westward from Gaviota Canyon, and thinning considerably on the north flank. It has been mapped previously as the Tejon formation.

The Eocene-Oligocene series has been subdivided into five lithologic units mappable throughout the western Santa Ynez Range. They are, starting with the lowest, Anita shale, Matilija sandstone, Cozy Dell shale, Sacate formation, and Gaviota formation. The lower Oligocene Gaviota formation is confined to the western Santa Ynez Range. The four Eocene units are the same lithologic units as those recognized in the eastern Santa Ynez Range as brought out by areal mapping of the whole range. The Anita shale of the western portion corresponds to what is called in unpublished reports the Juncal formation of the eastern Santa Ynez Range, and the Sacate formation corresponds to the "Coldwater" sandstone in the eastern Santa Ynez Range. The names Matilija and Cozy Dell have been retained. The type localities of both are in Matilija Canyon, Ventura County. All four of these units can be traced westward to San Marcos Pass, where all but the "Coldwater" dip under a cross-syncline, but reappear to the west. It must be emphasized that these formations were mapped throughout the Santa Ynez Range as lithologic, not as time units, and that their boundaries are not everywhere contemporaneous. Some units are difficult to differentiate locally, but their lithologic character is fairly persistent.

As the name "Coldwater" is preoccupied twice in American literature, Kelley [16] proposed the name Sacate for the "Coldwater" formation in the western Santa Ynez Range.

[16] Op. cit., p. 10.

The Sacate-Gaviota problem is one difficult to solve. The Gaviota formation has been separated from the Sacate in the western Santa Ynez Range because of its distinct faunal content, but it is lithologically nearly similar to the Sacate. The contact has been designated by a faunal break and slight lithologic change at the type area of the Gaviota formation on the south flank of the range. On the north flank the two are difficult to separate and are therefore mapped together as Sacate-Gaviota.

Eocene at Wons Canyon

On the east side of Wons Canyon, on the east edge of Los Olivos quadrangle, about 1600 feet of Eocene sediments lie unconformably on the Espada shale and are unconformably overlain by the upper Monterey shale.

The Eocene mapped as Anita shale in Wons Canyon consists of dark-gray siltstone and fine nodular sandstones ranging in thickness from less than 1 foot to 300 feet. The Matilija comprises about 200 feet of cobble conglomerate composed of well-rounded cobbles of quartzite and acidic igneous rocks in buff sandstone matrix, overlain by about 500 feet of medium-grained buff sandstone which grades upward into a fine-grained greenish-brown nodular sandstone about 500 feet thick.

Molluscan fossils occur in the nodular sandstones near the base of the Anita shale and also in the upper nodular sandstones of the Matilija. Both localities have yielded *Turritella uvasana, Ostrea idriaensis* Gabb. and *Galeodea* sp.

Sierra Blanca Limestone

The Sierra Blanca limestone is well developed at the base of the Eocene section in the San Rafael Mountains where it was named and described by Nelson.[17] and Keenan.[18] In the Santa Ynez Mountains it occurs at only three localities.

The most prominent exposure of Sierra Blanca limestone occurs in Nojoqui Canyon at Live Oak Ranch dairy. Here it consists of about 50 feet of gray-white, hard, sandy, algal limestone. It extends up both sides of the canyon to the west, where it rests with a well-exposed angular unconformity on the Jalama formation. This basal limestone extends up the ridge south of the canyon for some 2 miles before it lenses out to the west.

A small lens of Sierra Blanca limestone as much as 20 feet thick and a quarter of a mile long occurs on the south side of Jalama Canyon $1\frac{1}{3}$ miles southeast of the point where the road enters the canyon from the north. Here it occurs in the Anita shale about 250 feet below the top. It is of the same character as the Nojoqui Canyon exposure and contains abundant orbitoidal foraminifera.[19]

At Los Sauces Creek, 1 mile south of Tranquillon Mountain, a thin lens of Sierra Blanca limestone [20] overlies buff sandstone (Eocene ?) which rests on the Espada formation. The limestone here contains abundant orbitoidal foraminifera.

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[17] Op. cit.

[18] Keenan, M. F., The Eocene Sierra Blanca limestone at the type locality in Santa Barbara County, California: San Diego Soc. Nat. Hist. Trans., vol. 7, no. 8, pp. 53-84, 1932.

[19] For a description of the foraminifera see Woodring, W. P., op. cit. 1930, p. 157, pl. 17.

[20] For a description see Woodring, W. P., op. cit. 1930, p. 157.

The following species of orbitoidal foraminifera occur in the Sierra Blanca limestone at Jalama Canyon:

Discocyclina psila Woodring
Actinocyclina aster Woodring
Operculina or Nummulites
Gypsina

On the west side of Ramajal Canyon north of Jalama Creek a sandy phase of the Sierra Blanca limestone carries the following molluscs:

"Macrocallista" conradiana ? Gabb
Amaurellina inezana Conrad

The Sierra Blanca limestone is assigned to the middle Eocene.

Anita Shale

The Anita shale consists of about 1000 feet of clay shale lying above the Jalama formation and below the Matilija sandstone. It has been named and described by Kelley;[21] the type locality is on the south side of upper Santa Anita Canyon.

The Anita shale in the western Santa Ynez Mountains consists of dark-gray moderately well bedded clay shales and some thin beds of greenish-brown highly micaceous sandstone. At Santa Anita Canyon the middle portion contains thin calcareous sandstone beds with orbitoidal foraminifera. About 30 feet of highly foraminiferal red and green clay shale, known as the ''Poppin shale,'' occurs from 200 to 400 feet below the top of the Anita. The red and green colors are due to iron oxides, which occur in large quantities. This colored shale commonly contains calcite veinlets.

The Anita shale is about 1000 feet thick at Jalama and Santa Anita Canyons, and also in the higher Santa Ynez Range. On Santa Rosa Ridge it thins to about 300 feet, and to the north it buttresses out. It thins out likewise in Jalama and Salsipuedes Canyons and in Cañada Honda.

The relationship of the Anita shale to the overlying Matilija sandstone is accordant, although Kelley [22] reports a disconformity. The relationship of the Anita shale to the underlying Jalama formation appears to be conformable, but in the northerly exposures the Anita rests unconformably on the Jalama or older formations. The iron oxides in the Poppin shale were probably derived from basic rocks of the Franciscan to the north. The Poppin shale and Sierra Blanca limestone in Jalama Canyon occur at about the same horizon in the Anita shale, and it is possible that this horizon may be the base of the Eocene section of the Santa Ynez Range.

The upper portion of the Anita shale, especially the Poppin shale, has yielded a large foraminiferal fauna.[23] On the basis of this fauna, and of the occurrence of the Sierra Blanca limestone at about the same horizon, the upper Anita shale is assigned to upper middle Eocene. The lower portion of the Anita shale has yielded no foraminifera, and its age is therefore unknown. It may be middle or lower Eocene or Upper Cretaceous.

Matilija Sandstone

The Matilija sandstone in the western Santa Ynez Mountains consists of about 1000 feet of sandstone lying conformably between the Anita shale below and the Cozy Dell shale above.

[21] Op. cit., p. 6.
[22] Op. cit., p. 7.
[23] For listing, see Kelley, F. R., op. cit., p. 8.

The Matilija sandstone attains a maximum thickness of about 1200 feet in the higher Santa Ynez Range east of Las Cruces, but thins down to about 400 feet at Refugio Pass, then thickens eastward to 2000 feet at Santa Ynez Peak. Between Las Cruces and Jalama Canyon the Matilija is from 500 to 1000 feet thick. Northward it thins rapidly, being less than 300 feet thick in the Santa Rosa Hills and in areas to the west. Where the underlying Anita shale buttresses out the Matilija sand rests unconformably on the Cretaceous or Franciscan.

The Matilija is made up of a succession of beds up to 25 feet thick of massive, medium-grained fairly hard bluish-white sandstone which weathers buff. The sandstone beds are separated by thin partings of micaceous sandy shale. The basal portion locally contains an algal reef and some rounded cobbles of quartzite and granitic rocks.

The Matilija sandstone is highly resistant to erosion and forms the highest strike ridges of the western Santa Ynez Mountains. Most of it supports brush.

At the Gaviotito-Santa Anita divide and also in the Santa Rosa Hills the Matilija has yielded the following diagnostic molluscs:

Pelecypoda
- Macrocallista hornii Gabb
- Gari hornii (Gabb)
- Nemocardium linteum (Conrad)
- Pitar uvasanus (Conrad)
- Schedocardia cf. brewerii (Gabb)

Gastropoda
- Amaurellina aff. moragai (Stewart)
- Ectinochilus canalifer supraplicatus (Gabb)
- Ficopsis hornii (Gabb)
- Ficopsis remondii (Gabb)
- Ficus mamillatus (Gabb)
- Galeodea susanae (Schenck)
- Olequahia cf. hornii (Gabb)
- Seraphs erratica Cooper
- Turritella uvasana Conrad
- Turritella applinae Hanna
- Turritella scrippsensis M. A. Hanna

This fauna places the Matilija sandstone in early upper Eocene, or in the so-called molluscan "Transition stage" of Clark and Vokes.[24]

Cozy Dell Shale

In the western Santa Ynez Range the Cozy Dell shale consists of about 700 feet of well-bedded shale lying conformably on the Matilija sandstone and grading upward into the Sacate formation.

The Cozy Dell shale maintains a fairly uniform thickness of about 700 feet throughout the western Santa Ynez Mountains, although it is somewhat thicker in the higher Santa Ynez Range.

The lower half of the Cozy Dell shale consists of well-bedded, but easily weathered gray clay shales with spheroidal fracture. This portion contains one, or locally several, thin beds of hard greenish sandstone 180 feet from the base. The upper half of the Cozy Dell consists of the same type of shale but with two members of thin-bedded, slightly siliceous harder brown clay shales which weather pale gray and form prominent exposures. The upper member locally carries gray limestone nodules that weather yellow. The Cozy Dell shale grades upward through a series of thin sandstone interbeds into the overlying Sacate sandstone.

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[24] Clark, B. L., and Vokes, H. E., Summary of marine Eocene sequence of western North America: Geol. Soc. America Bull., vol. 47, no. 6, pp. 851-878, 1936.

The Cozy Dell shale is non-resistant to erosion, forming saddles across ridges or amphitheaters in canyons between more resistant Matilija and Sacate sandstones. It forms grassy slopes.

The lower half of the Cozy Dell shale has yielded an upper Eocene foraminiferal fauna. The species listed by Kelley [25] correlate it with Laiming's zone A-2.[26] The upper half of the Cozy Dell shale has not yielded a diagnostic fauna.

Sacate ("Coldwater") Formation

In the western Santa Ynez Mountains the Sacate (or "Coldwater") formation consists of about 1000 feet of interbedded sandstone and shale conformable between the Cozy Dell shale below and the Gaviota formation above. The type locality of the Sacate formation is at Sacate Canyon; this section is described by Kelley.[27]

The Sacate formation consists of sandstone and shale interbedded in about equal amounts. The sandstone beds are fine to medium grained, hard, well bedded to massive, highly micaceous, bluish gray when fresh, but weather to buff. The hard thin beds form large slabs. The interbedded shales are gray, well bedded to laminated, highly micaceous, sparingly foraminiferal. Thin layers of hard brown conglomerate occur locally, with rounded pebbles of porphyritic igneous rock and some Franciscan red cherts in a hard sandstone matrix commonly containing oyster shells. The uppermost 200 to 500 feet of Sacate on the south flank of the range consists of brown slightly organic massive to well-bedded clay shale. On the south flank the Sacate formation is well exposed. Here the hard sandstone beds form prominent ledges.

Both the upper and lower contacts of the Sacate formation are gradational and thus difficult to map. The base is placed at the first appearance of numerous sandstone beds which form a prominent topographic break. West of Las Cruces the top is placed at the contact between the organic shale member below, which carries an Eocene fauna, and the massive, poorly exposed siltstone above, which carries a Refugian fauna and is therefore assigned to the Gaviota formation. East of Gaviota Canyon this siltstone grades laterally into sandstone, so that all of the 500 feet of shale there underlying the Gaviota sandstone is mapped with the Sacate.

In the Santa Rosa Hills and San Julian Ranch the Sacate is predominantly shale with thin sandstone interbeds. It grades upward into the Gaviota formation which is mainly sandstone, but because of poor exposures and lack of faunal control, the contact has not been determined. The formations are therefore mapped together as Sacate-Gaviota.

The Sacate formation carries the following megafossils: [28]

Pelecypoda
- Venericardia cf. hornii (Gabb)
- Ostrea idriaensis Gabb

Gastropoda
- Amaurellina sp.
- Cypraea sp.
- Turritella variata var. juliana Merriam

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[25] Op. cit., p. 11.
[26] Kelley, F. R., op. cit., p. 10.
[27] Op. cit., pp. 10-12.
[28] Kelley, F. R., op. cit., p. 13.

This meager fauna and the stratigraphic position of the Sacate formation place it in uppermost Eocene, equivalent to Clark and Vokes' molluscan "Tejon stage." The Sacate has yielded a foraminiferal fauna correlative with Laiming's zone A-1.

Gaviota Formation

The Gaviota formation consists of about 1600 feet of thick-bedded sandstone and siltstone conformable between the Sacate formation below and the Alegria sandstone above. The type area of the Gaviota formation is on the south slope of the Santa Ynez Range between Gaviota and Bulito Canyons; the type locality is at Cañada de Santa Anita.[29]

The type Gaviota formation west of Las Cruces is about 1600 feet thick and consists of three members, each about 500 feet thick. The lower member is a massive soft gray siltstone; the middle member is light buff, thick-bedded, well-sorted fine- to medium-grained concretionary sandstone; the upper member is gray sandy siltstone with some interbedded fine-grained sandstone. On the south flank of the range east of Gaviota Canyon, and on the north flank of the Santa Ynez Mountains, the upper member grades into sandstone; east of Tajiguas Canyon the lower member also becomes sandstone. The sandstones of the Gaviota formation are highly resistant to weathering and thus form prominent brush-covered outcrops. The siltstone members are easily weathered to low grassy slopes.

The Gaviota formation is of shallow marine origin, and the sandstones are richly fossiliferous. A prominent fossil reef composed largely of *Crassatella collina* occurs at the top of the middle member near Las Cruces and near the San Julian ranch house. Foraminifera are abundant in the siltstone members.

The following molluscs are abundant in the Gaviota formation:

Pelecypoda
- Crassatella collina Conrad
- Ostrea tayloriana Gabb
- Pecten (Chlamys) yneziana Arnold
- Tivela inezana Conrad
- "Cardium brewerii" Gabb (large, of Arnold & Anderson 1907)
- Venericardia hornii Gabb

Gastropoda
- Turritella variata Conrad
- Ficus gesteri Wagner & Schilling
- Siphonalia merriami Wagner & Schilling

Venericardia hornii has been regarded as an Eocene marker, but the rest of the molluscan fauna is unlike that of any other Eocene fauna of California. The foraminiferal fauna is also unlike that of the California Eocene. Because of the strange fauna Schenck and Kleinpell[30] designate the Gaviota formation at the type locality as the type "Refugian stage," which they assign to lower Oligocene.

Bed by bed mapping of the Gaviota formation on the south slope of the Santa Ynez Range from Gaviota Canyon eastward to San Marcos Pass shows that the upper portion grades laterally eastward through coarse littoral sands into the basal pink conglomerate and red beds of the lower part of the Sespe formation, the contact becoming successively lower from west to east. The lower portion of the Gaviota sandstone

[29] Effinger, W. L., Gaviota formation of Santa Barbara County, California: Geol. Soc. America Proc. 1935, pp. 351-352, 1936.
[30] Op. cit.

grades eastward into the upper Sacate ("Coldwater") sandstone from which it is not differentiated.

Alegria Formation

The Alegria formation is the marine facies of the continental Sespe formation in Gaviota and Point Conception quadrangles. The Alegria consists of about 1200 feet of sandstone and a minor amount of siltstone lying conformably above the Gaviota formation and disconformably below the Vaqueros formation.

The Alegria formation, generally known as "marine Sespe," is developed only on the south flank of the Santa Ynez Range between a point 4 miles north of Point Conception and Capitan Canyon. The type locality is designated as the ridge east of Cañada de Santa Anita, where the section is as follows:

Vaqueros sandstone and conglomerate.
Disconformity

G	Buff, laminated friable fine- to medium-grained sandstone	250′
F	Poorly exposed soft greenish siltstone. Thickens eastward, lenses out westward	10′
E	Gray-white to buff, friable medium- to fine-grained sandstone. Becomes pebbly eastward	110′
D	Soft light gray-brown poorly to well-bedded siltstone and thin layers of very fine sand	150′
C	Light-buff friable massive to thick-bedded medium-grained sandstone; lower 90 feet gray, coarse grained, and contains several oyster reefs	230′
B	Soft greenish-brown silty to sandy clay shale	80′
A	Light-buff to gray friable massive sandstone with few small rounded pebbles	180′
	Total	1010′

Conformity
Gaviota siltstone

These members vary along the strike in lithology and thickness, but the above type of lithology is characteristic of the Alegria formation throughout its extent. It is made up predominantly of medium- to coarse-grained, thick-bedded sandstones which form prominent exposures. They are generally fossiliferous and are shallow-marine littoral deposits. In the most westerly exposure siltstone members B and D become somewhat brown and organic and weather pale gray. Eastward from Alegria Canyon member G thickens to more than 600 feet. From Agua Caliente Canyon the Alegria formation grades laterally eastward into the nonmarine Sespe formation, with the first red clays appearing in member G at Gaviota Canyon, but green clays of possible nonmarine origin persist in this member as far west as Cuarta Canyon. Eastward from Gaviota Canyon, red clays appear progressively lower in the section, until at Capitan Canyon they occur throughout the section, which apparently is all nonmarine. The standstones retain their buff color even where they become unfossiliferous and supposedly nonmarine, so that it is difficult to determine just where the Alegria formation grades into Sespe. Bailey [31] extends the Sespe nonmarine beds as far west as Santa Anita Canyon. The contact between the predominantly marine Alegria formation and the predominantly nonmarine Sespe is shown approximately on the geologic map.

[31] Bailey, T. L., Origin and migration of oil into Sespe red beds, California: Am. Assoc. Petroleum Geologists Bull., vol. 31, no. 11, pp. 1913-1935, 1947.

The Alegria formation lies conformably upon the upper siltstone member of the Gaviota formation. Eastward from Arroyo Hondo, where the upper Gaviota becomes sandstone, the two formations are difficult to differentiate. The relationship of the Alegria to the overlying Vaqueros is an unconformity, as indicated by gradual overlap of successive beds of the former from east to west; west of Cojo Canyon there is an angular discordance of about 15°.

At Bulito Canyon the top of member C of the Alegria carries the following molluscan species:

Ostrea tayloriana Gabb
Pecten (Chlamys) yneziana Arnold
Tivela inezana Conrad
Turritella variata Conrad

This fauna is the same as that of the underlying Gaviota formation, and thus places the Alegria in the Refugian stage of the Oligocene. Kleinpell [32] reports a Zemorrian microfauna from green siltstone west of Gaviota Canyon, which is believed to be member F of the Alegria formation.

Sespe Formation

The Sespe formation in the western Santa Ynez Mountains is a series of continental sandstones, clays, and conglomerate lying above the Gaviota or older formations and below the Vaqueros sandstone.

The Sespe formation is best developed on the south slope of the Santa Ynez Range in the vicinity of Capitan and Corral Canyons. Here it consists of about 2200 feet of pinkish-gray to buff friable laminated sandstone interbedded with red and green clays and silts. Westward along the strike the prevailing pink color of the sandstones gives way to gray and buff. Only the fine sediments retain their red color. The thick basal conglomerate of the Sespe in the Santa Barbara-Goleta area is not present in the area mapped. Between Refugio and Gaviota Canyons progressively lower beds of the Sespe formation grade laterally westward into the marine Alegria formation.

In the Santa Rosa Hills and eastward to Quiota Canyon the Sespe formation averages about 500 feet in thickness and consists of coarse basal green conglomerate composed almost entirely of Franciscan debris, grading upward into red and green friable sandstone and interbedded variegated clays and silts. Here the Sespe lies on Gaviota or older formations with a great regional unconformity, but grades upward into Vaqueros marine beds. In this area the Sespe is of Zemorrian age (lower Miocene) as it unconformably overlies the Gaviota formation of Refugian age, and in part grades into marine Vaqueros in the western Santa Rosa Hills. On San Julian ranch, however, the Sespe is overlapped on the northwest by the marine Vaqueros conglomerate.

Vaqueros Formation

The Vaqueros formation in the western Santa Ynez Mountains consists of as much as 600 feet of marine sandstone and conglomerate of Zemorrian age (lower Miocene) lying above the Sespe, Alegria, or older formations and conformably below the Rincon shale.

On the south slope of the range the Vaqueros sandstone forms a very prominent and continuous brush-covered ledge from Bixby Canyon,

[32] Schenck and Kleinpell, op. cit.

north of Government Point, for some 27 miles eastward across Point Conception and Gaviota quadrangles. Between Cañada del Capitan and Arroyo Hondo the Vaqueros consists of about 200 feet of light-gray, friable to hard calcareous, cross-bedded medium- to coarse-grained sandstone. Westward the lower portion becomes pebble conglomerate. At Gaviota Canyon the Vaqueros thins down to 25 feet, but thickens again toward the west and averages about 75 feet west of Alegria Canyon.

The Vaqueros formation is best developed on the north flank of the Santa Ynez Mountains in the vicinity of Nojoqui and Alisal Canyons. Here it is about 600 feet in maximum thickness and consists of light greenish brown concretionary fine- to medium-grained sandstones interbedded with massive gray siltstones. In this area the Vaqueros grades downward into the underlying Sespe and upward into the Rincon shale.

In San Julian Valley and westward to the Tranquillon Mountain area, the Vaqueros consists of as much as 300 feet of buff sandstone grading downward into greenish-brown fossiliferous, cross-bedded basal conglomerate composed almost entirely of Franciscan debris.

On the south slope of the Santa Ynez Range, eastward from Gaviota Canyon, the Vaqueros sandstone lies with a sharp, possibly disconformable, contact on the Sespe, but no conclusive evidence of an unconformity is indicated here. Farther west, the Vaqueros gradually overlaps the upper members of the Alegria, and west of Cojo Canyon this becomes an angular unconformity. A great regional unconformity becomes strongly developed throughout the northwestern part of the Santa Ynez Mountains, where the Vaqueros overlaps the eroded edges of the Gaviota and older formations which had previously been compressed into broad folds trending slightly north of west. A nearly similar condition holds true for the unconformity at the base of the Zemorrian Sespe in the Nojoqui-Alisal area, which was probably developed at the same time or slightly earlier.

The Vaqueros formation contains the following molluscan species in the western Santa Ynez Mountains:

Pelecypoda
- Ostrea eldridgei Arnold (large)
- Pecten (Pecten) vanvlecki Arnold
- Pecten (Lyropecten) magnolia Conrad
- Pecten (Chlamys) sespeensis Arnold
- Trachycardium vaquerosensis Arnold
- Macoma nasuta (Conrad)

Gastropoda
- Turritella inezana Conrad
- Turritella inezana var. altacorona
- Rapana vaquerosensis (Arnold)

Pecten (Lyropecten) magnolia and *Turritella inezana* are abundant in the basal conglomerate throughout the northwestern Santa Ynez Mountains. The other species occur more abundantly in the Vagueros sandstone.

The above fauna places the Vaqueros formation of the Santa Ynez Mountains in the Zemorrian stage, lower Miocene.

A. VIEW WEST ALONG SANTA YNEZ RANGE FROM HEAD OF JALAMA CANYON

Formations dip southwest into Jalama syncline. Nearer brush-covered spur formed by Jalama upper sandstone, farther one by Matilija sandstone; Anita shale between. Distant hills made up of Miocene formations. *Photo by H. G. Schenck, 1941.*

B, VIEW EAST ALONG WESTERN SANTA YNEZ MOUNTAINS FROM HEAD OF EL BULITO CANYON

Type exposure of Jalama formation showing fossiliferous sandstones at left of canyon, upper shale member and sandstone at right. *Photo by H. G. Schenck, 1941.*

A, VIEW WEST ACROSS CAÑADA DEL GATO ON SOUTH FLANK OF SANTA YNEZ MOUNTAINS

Matilija sandstone beds at right, overlain by Cozy Dell shale at middle, in turn overlain by Sacate sandstone, which forms peak at left of picture. *Photo by H. G. Schenck, 1941.*

B, VIEW NORTHEAST FROM GAVIOTA SHOWING OUTCROPS OF ALEGRIA SANDSTONE

Skyline ridge formed by Gaviota sandstone.

A, ANGULAR UNCONFORMITY BETWEEN EOCENE FOSSILIFEROUS SAND-STONE (MATILIJA) AND CRETACEOUS SHALE (JALAMA?)
Beds dip southwest; 3.3 miles south of Buellton, 0.3 mile west of Nojoqui Creek.

B, VIEW WEST ACROSS NOJOQUI CANYON 2.5 MILES SOUTH OF BUELLTON
Light-colored beds on high bluffs are Vaqueros sandstone, underlain by "Sespe" conglomerate and Cozy Dell shale, which form grassy slopes. Lower brush-covered hills are Jalama? formation.

A, VAQUEROS CONGLOMERATE IN RAMAJAL CANYON
0.7 mile north of Jalama Creek, 4.6 miles east of mouth. Conglomerate contains abundant *Pecten magnolia* and *Turritella inezana*. Bed dips 85° N. (to right).

B, STEEPLY DIPPING LIMESTONE BED
In Member B, lower Monterey shale, east of Alegria Canyon.

Rincon Claystone

The Rincon claystone is about 1500 feet thick and lies conformably above the Vaqueros sandstone in the Santa Ynez Mountains.

On the south flank of the range the Rincon forms a continuous exposure adjacent on the south to the Vaqueros sandstone across Point Conception and Gaviota quadrangles. It is also well exposed through Quiota, Alisal, and Nojoqui Canyons, in the Santa Rosa Hills, San Julian and Jalama Canyons, and in the Tranquillon Mountain area. The Rincon lies conformably on the Vaqueros everywhere except on Tranquillon Mountain ridge, where it lies unconformably on the Espada formation, the Vaqueros having buttressed out. The relationship with the overlying Monterey is conformable except in the northwestern Santa Ynez Mountains, where it is unconformable.

The Rincon formation at all exposures is made up of brown-gray poorly bedded to massive clay shale with spheroidal fracture; yellow-weathering calcareous concretions are common. In the more northerly exposures in San Julian Valley and at Tranquillon Ridge the Rincon claystone is somewhat hard and weathers nearly white, probably because of its siliceous or bentonitic material content. The Rincon readily weathers into a clayey adobe soil which forms low grass-covered slopes, in marked contrast to the brush-covered Vaqueros sandstone outcrops.

The lower third of the Rincon claystone carries an upper Zemorrian (lower Miocene) foraminiferal fauna. The upper two-thirds of the Rincon carries a Saucesian (upper lower Miocene) foraminiferal fauna.

Lospe Formation

The Vaqueros-Rincon formations are not known to occur in the Santa Maria Basin, but may be represented by the lower Miocene (?) Lospe formation, consisting of 2700 feet of terrestrial reddish and greenish sediments and lenses of white indurated tuff, exposed in the Casmalia Hills. This section starts with a basal conglomerate of debris derived from the underlying Franciscan, and grades upward through bedded sandstones into gypsiferous mudstone which is overlain by the Relizian Point Sal formation.

The Lospe formation underlies Casmalia and Orcutt oil fields, and may underlie Burton Mesa and Lompoc oil field; for several wells penetrated a thin series of gray and reddish sandstones and tuffaceous (?) rocks between the Monterey shale and Franciscan, which may be either the Lospe formation or the equivalent of the Tranquillon volcanics or Obispo tuff.

Tranquillon Volcanics

The Tranquillon volcanics are a local phase of the Obispo tuff of San Luis Obispo County, and are composed of as much as 1200 feet of rhyolite, agglomerate, and ash exposed on Tranquillon Mountain ridge and vicinity. Here this volcanic series lies conformably below the Monterey shale and unconformably above Rincon and older formations. It is generally regarded as the basal member of the Monterey formation, but since it is a rock unit distinct from any other in this area, it is treated as a formation. The type locality is designated as the ridge west of Cañada del Rodeo.

The Tranquillon volcanics are made up mainly of a large rhyolite flow which forms Tranquillon Peak and the large dip-slope on the south side of this same ridge. The rhyolite is buff colored, dense to slightly porphyritic, and shows prominent flow-structure. The flow lenses out east and west of the ridge, and is replaced by rhyolite agglomerate and tuff at Point Pedernales and in the vicinity of Jolloru Canyon. The rhyolite may have erupted along the ridge immediately north of Tranquillon Peak or from the exposure north of Cañada Honda Creek, but its source is not definitely known.

East of Jolloru Creek the Tranquillon volcanics lens out, but reappear locally in other parts of the western Santa Ynez Mountains. At Bixby Canyon 3 miles north of Government Point they appear as a lens up to 50 feet thick of rhyolite tuff-breccia at the base of the Monterey shale. Farther east they are represented by local occurrences of bentonite at this horizon.

Other exposures of Tranquillon volcanics occur along the Santa Ynez River in the vicinity of the Santa Rita Hills, comprising basalt, basaltic agglomerate, tuff, and bentonite totaling 500 feet in maximum thickness. About 690 feet of basalt was drilled through in Tidewater Associated Oil Co. No. "Leonis" 1 well.

On the south side of the Santa Ynez River south of Solvang is a quarry in which about 75 feet of Tranquillon formation, composed of sandstone, hard indurated tuff, and algal limestone, is exposed.

At Quiota Canyon the Tranquillon formation is represented by about 30 feet of pumice tuff and bentonite on the hill southwest of the canyon. On the east side of this canyon is about 60 feet of medium-grained buff sandstone with a 5-foot layer of bentonite and pumice tuff near the middle.

In El Jaro Canyon below the juncture with Amoles Creek is a layer of limestone about 50 feet thick, at the base of the Monterey shale. The basal portion contains tuff, sandstone, and conglomerate which may be equivalent to the Tranquillon volcanics.

The Tranquillon formation is upper Saucesian in age (upper lower Miocene). This is indicated by the presence of upper Saucesian foraminifera at Capitan Beach, in the upper Rincon shale underlying the Tranquillon bentonite bed, and also in the overlying basal Monterey shale. On the basis of microfauna the Tranquillon volcanics definitely correlate with the Obispo tuff at the mouth of Cuyama River. On the east side of Quiota Canyon the sandstone of the Tranquillon formation carries the following molluscs:

Pecten (Amusium) lompocensis Arnold
Pecten (Lyropecten) estrellanus (Conrad)
Pecten (Lyropecten) magnolia Conrad
Turritella ocoyana Conrad
Turritella temblorensis Wiedey

Monterey Shale

The term Monterey shale, as used in this report, includes all the sediments lying above the Rincon shale (and above the Tranquillon volcanics where present), and below the Sisquoc formation. The Monterey shale as herein used is the same as the Modelo formation of the Ventura Basin. The Monterey shale is made up of predominantly siliceous shales ranging in age from uppermost Saucesian to lower Delmontian of the Miocene. The Monterey shale herein includes the Relizian Point Sal formation of the northern Santa Maria Basin as mapped by Woodring and others,[33]

[33] Op. cit., 1944.

as this unit loses its identity as a formation and becomes inseparable from the Monterey shale in the Santa Ynez Mountains and southern Santa Maria Basin.

Throughout the area mapped the Monterey shale is divisible into two lithologic members, lower and upper. The lower Monterey is characterized by a mixture of clayey shales, siliceous shales, and limestones, and the upper Monterey by siliceous shales. The upper Monterey as used in this report corresponds to the "Middle and Upper member" of the Monterey as mapped [34] in the northern Santa Maria Basin, and the lower Monterey to the "Lower member" of the Monterey and the Point Sal formation.

In the Santa Ynez Mountains the Monterey shale averages about 1700 feet in thickness, and both members are well exposed. In the portion of the Santa Maria Basin mapped the Monterey shale is present nearly throughout, but is buried by later formations except in Burton Mesa and eastern Purisima Hills, where the upper member crops out. The Monterey shale ranges from 1800 to 4500 feet in thickness in the Santa Maria Basin.

Santa Ynez Mountains. The Monterey shale is well exposed in the Santa Ynez Mountains where it ranges from 1200 to 2000 feet in thickness. On the south flank of the range, and in the Santa Rosa Hills, the Monterey lies conformably on the Rincon. However, elsewhere in the Santa Ynez Mountains, especially throughout the northwestern portion, the Monterey shale, or the Tranquillon volcanics where present, lie unconformably on the eroded surface of older formations ranging from Rincon to Franciscan. The relationship of the Monterey to the overlying Sisquoc is conformable except for a local disconformity developed in the Santa Rita Hills and on the coast west of Gaviota.

The Monterey shale is well exposed on the south flank of the Santa Ynez Range west of Gaviota. Here the section is divisible into five lithologic members, each with a distinct microfauna.

The sequence shown in the section (page 36) holds true for most of the Santa Ynez Mountains, but because of structural complexity and poor exposures the various members cannot everywhere be mapped.

In the Santa Ynez Mountains the lower Monterey shale averages about 800 feet in thickness, and attains its maximum of 1800 feet at San Pascual Canyon. It locally buttresses out against older formations in Salsipuedes Canyon, and also at San Lucas Canyon. The lower Monterey consists of a heterogeneous series of well-bedded shales of various types, composed of soft phosphatic shales, fissile organic shales, impure diatomite and siliceous shales, and interbedded limestone beds. Thin layers of volcanic ash are common. Layers of clay shale and siltstone are common in the lower (Relizian) portion. From Cañada de la Vina westward the lower Mohnian portion grades laterally into cherty shale which is mapped with the upper Monterey. In the vicinity of Tranquillon Mountain the entire lower Monterey shale is largely composed of cherty shale which is difficult to separate from the upper Monterey.

The lower Monterey is weakly resistant to erosion but more resistant than the underlying Rincon. It tends to form landslides. The lower Monterey weathers to a deep heavy adobe soil which supports only grasses and annual herbs.

Throughout most of the Santa Ynez Mountains the upper Monterey shale averages about 950 feet, but it thickens to more than 3000 feet at

[34] Woodring, W. P., and others, op. cit., 1944.

Monterey shale section exposed on south flank of Santa Ynez Range between Cojo and Gaviota Canyons.

Sisquoc shale with basal sand and chert conglomerate east of Sacate Canyon.

Disconformity

UPPER MONTEREY	F	Hard laminated brown platy porcelaneous shale which weathers white. Carries lenses of chert conglomerate east of Cuarta Canyon. Abundant diatoms, sparse foraminifera. Delmontian stage, upper Miocene 100′-200′
	E	Hard laminated brittle opaline cherty shales grading into above member. Contains layers of dark chalcedonic chert westward from Gato Canyon. Sparse foraminifera. Upper Mohnian stage, upper Miocene___250′-550′
LOWER MONTEREY	D	Soft, laminated fissile diatomaceous shales; phosphatic shales; occasional thin limestones; minor porcelaneous and cherty shales. Abundant foraminifera. Lower Mohnian stage, upper Miocene____________150′-300′
	C	Hard white limestone and interbedded thin strata of soft diatomaceous shale, minor amounts of phosphatic shale, and laminated siliceous shale. Abundant foraminifera, especially *Valvulineria californica* and *Siphogenerina collomi*. Luisian stage, middle Miocene____ ____________________________________150′-180′
	B	Soft buff-weathering bedded to massive siltstone, silty siliceous shale, and buff-weathering limestone beds. Foraminifera abundant locally. Relizian and uppermost Saucesian stages, middle Miocene______160′-460′
	A	Bentonite, equivalent to Tranquillon volcanics__0′-10′
		Aggregate thickness______1010′-1440′

Conformity
Rincon clay shale

San Lucas Canyon. On the south flank eastward from Gato Canyon and on the north flank eastward from Solvang the upper Monterey is characterized by hard, brown, platy porcelaneous shale. On both flanks of the range this grades westward into opaline cherty shales, which in the extreme western Santa Ynez Range contain numerous layers of heavy contorted chalcedonic chert.

Phases of pure punky laminated diatomite are locally interbedded in the cherty shale of the upper Monterey at Salsipuedes, San Miguelito, and Jalama Canyons. Most of these occur toward the top, but at Salsipuedes Canyon some occur far down the section. The 1000 feet of pure laminated diatomite overlying the Monterey siliceous shales at the Lompoc quarries and vicinity has been mapped as the lower Sisquoc formation. It is of Delmontian (upper Miocene) age. At the beach west of Gaviota Canyon are several lenses as much as 75 feet thick of well-bedded conglomerate in member F of the Monterey and at the base of the Sisquoc. This conglomerate is made up of unsorted angular to sub-rounded cobbles and pebbles composed mainly of Monterey cherty shale; there are also some pebbles of quartzite, porphyries, sandstone, etc. The matrix is a tar-soaked cross-bedded sand made up largely of quartz grains. The occurrence is remarkable, as at this locality the Monterey is made up of porcelaneous shale, and no cherty shale is present. The conglomerate is apparently the result of some local uplift and erosion at the end of deposition of the upper Monterey shale.

The upper Monterey siliceous shale is rather strongly resistant to erosion. Since the shales are hard but closely fractured they form high but rounded hills and narrow, steep-sided canyons. They develop little soil and generally support brush or oak timber, in contrast to the lower Monterey which forms open grasslands.

Santa Maria Basin. The Monterey shale underlies nearly all of the Santa Maria Basin mapped, but is generally concealed by younger formations. Only in Burton Mesa and eastern Purisima Hills the upper Monterey is exposed. However, data on the distribution and thickness of the Monterey shale where concealed have been furnished from well-logs.

On Burton Mesa and the south flank of the Purisima Hills the Monterey shale averages slightly less than 2000 feet, but thickens northward to some 4500 feet on the north flank of the Purisima Hills and perhaps under Los Alamos Valley and upper Santa Ynez Valley. Throughout most of the Burton Mesa, Lompoc Valley, and Purisima Hills the Monterey is underlain by Franciscan or Espada formations, except for some local intervening tuffaceous sediments thought to be the Lospe formation. This condition indicates a great regional unconformity at the base of the Monterey shale. The Monterey is conformably overlain by the Sisquoc diatomite in the Santa Maria Basin, except under the San Rafael foothills, where it is successively truncated northeastward by the Sisquoc. In the northeastern portion it is completely overlapped.

Both members of the Monterey shale are present in the Santa Maria Basin and their lithologic character is the same as in the Santa Ynez Mountains. The exposures of upper Monterey in Burton Mesa and eastern Purisima Hills consist of close-fractured cherty shale grading upward into porcelaneous platy shale.

AGE		FORMATION	LITHOLOGY	THICK.	DESCRIPTION
Recent		Alluvium		0-100	Silts and gravels
Pleistocene	upper	Terraces		0-100	Gravels
Pliocene	lower	Sisquoc.		3200+	Diatomaceous siltstone. Clay shale or diatomaceous mudstone. Thin-bedded clay shale or laminated diatomite.
? Miocene	upper				
Miocene	upper / middle	Monterey		1000'-3000'	Porcelaneous and cherty siliceous shales. Organic shales and thin limestones.
	lower	Tranquillon		0-1200'	Rhyolite and basalt lava, agglomerate, tuff, bentonite.
		Rincon		0-1700'	Claystone.
		Vaqueros		0-900'	Sandstone & conglomerate.
Oligocene		Sespe / Alegria		0-2000'	Pink to buff sandstone and red and green siltstone. Gray to buff marine sandstone.
		Gaviota		1600±	Fossiliferous buff sandstone and siltstone.
Eocene	upper	Sacate		1000'-1500'	Buff sandstone and clay shale.
		Cozy Dell		700'-2000'	Brown clay shale.
		Matilija		0'-2000'	Buff arkosic sandstone.
	middle	Anita		0'-1000'	Dark gray clay shale.
		Sierra Blanca		0-50'	Algal limestone lens.
Cretaceous	Upper	Jalama		2200'+	Buff fine-grained sandstone. Gray siltstone. Buff sandstones and gray clay shales.
	middle? and Lower	Espada		4000'+ to 6800'+	Dark greenish brown carbonaceous shales and thin sandstones. Basal pebbly sandstone.
? Jurassic	Upper	Honda		1500'	Dark greenish brown nodular claystone.
		Franciscan		?	Hard green sandstone and black shale. Serpentine intrusions.

FIGURE 2. Stratigraphic column, western Santa Ynez Mountains.

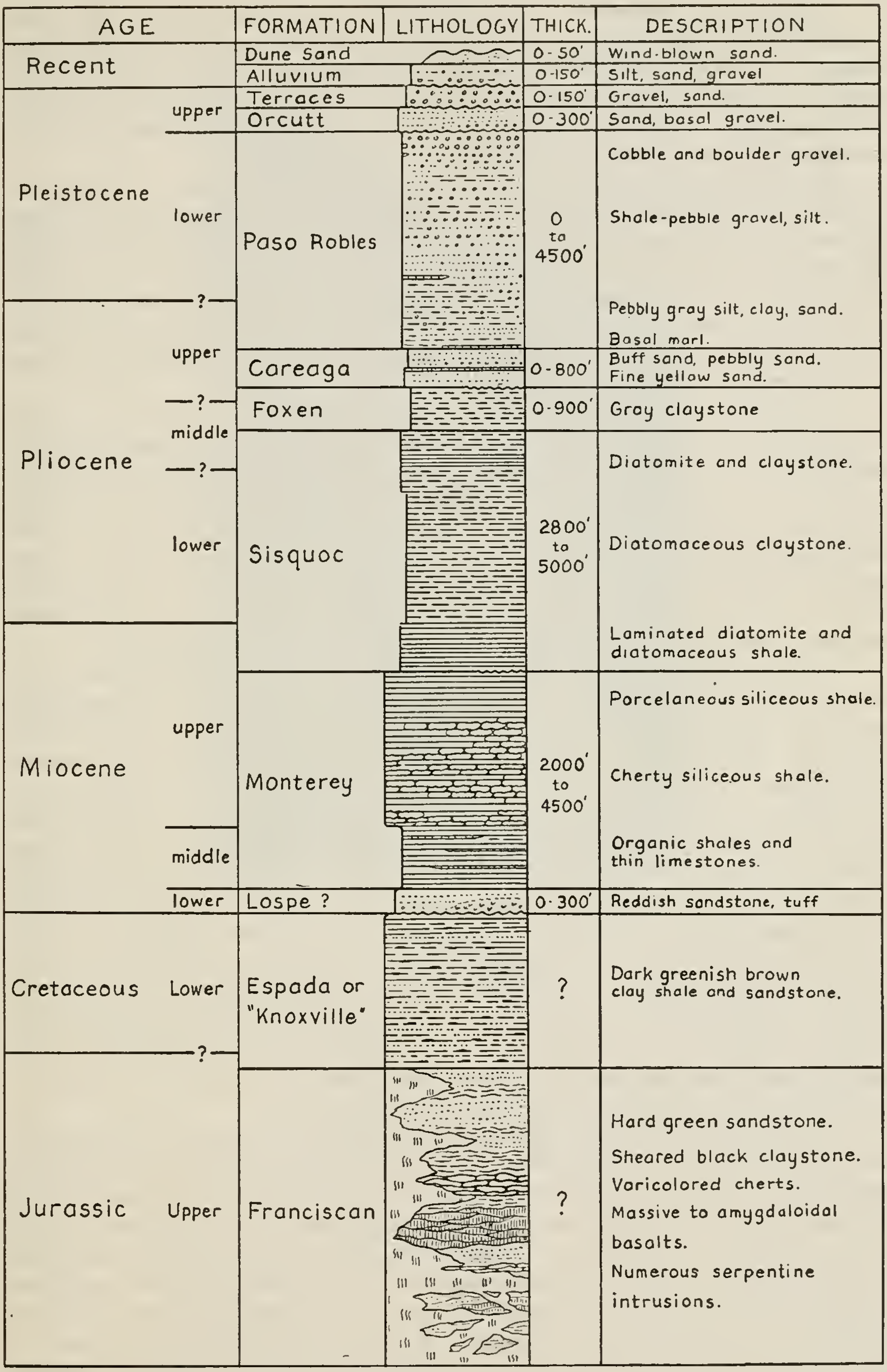


FIGURE 3. Stratigraphic column, southern Santa Maria Basin.

Lithologic Character. The Monterey shale differs from all other formations in the mapped area and is remarkable for the following reasons: (1) widespread areal extent; (2) low percentage of clastic sediment; (3) presence of volcanic material; (4) high percentage of chemical sediments; (5) very high percentage of siliceous sediments; (6) large amount of organic material; (7) rhythmic bedding.

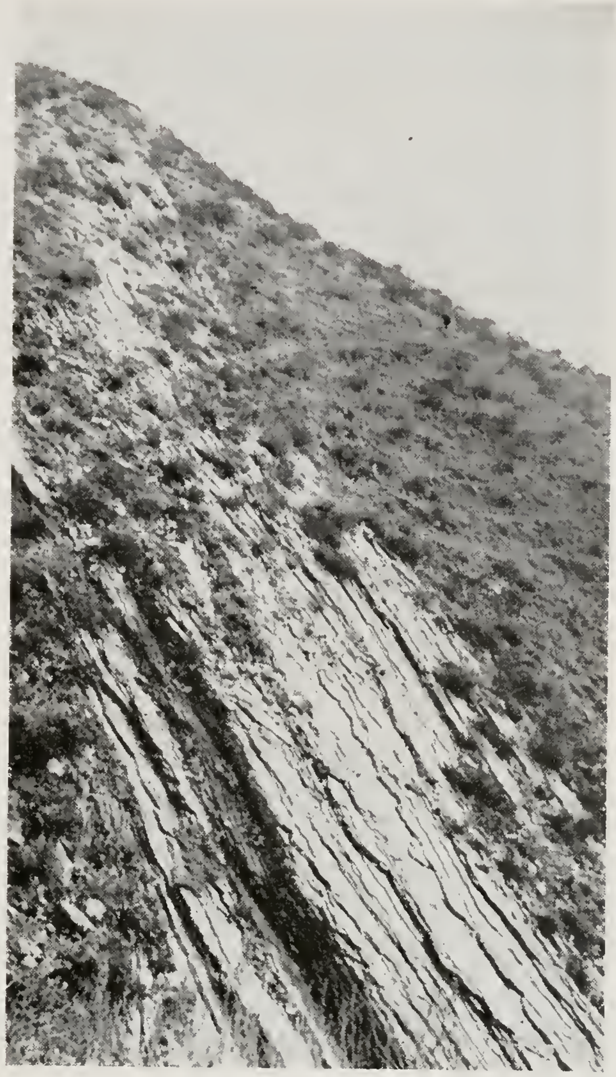
The Monterey shale, and perhaps the overlying Sisquoc, are the only Tertiary formations deposited over the entire mapped area. The local absence of Monterey shale under the northeastern San Rafael foothills and in parts of the Santa Ynez Mountains is due to its removal by uplift and erosion after deposition. The Monterey formation contains no marginal type sediments and there is no evidence that it was not deposited over the entire mapped area. Local absence of the lower Monterey, however, may be due to non-deposition.

The Monterey shale is the only formation in the mapped area containing almost no clastic material. Only the lowest (Relizian) portion contains an appreciable amount of silt and clay. This material decreases upward to almost none in the uppermost Monterey. Sand and conglomerate are absent except for the local occurrence of chert pebble conglomerate and sand west of Gaviota Beach. The general absence of clastic material in the Monterey formation is apparently due to widespread submergence under an open sea and disappearance of the adjacent land areas which furnished clastic materials to older formations.

The occurrence of the Tranquillon volcanics and Obispo tuff at the base of the Monterey strongly suggests that volcanism had strong influence on the deposition of the siliceous sediments that make up most of the Monterey. Thin layers of volcanic ash and some bentonite are common throughout the Monterey shale. The Tranquillon rhyolitic eruptions may have been a source of some of the enormous quantities of silica in the Monterey shale, either by means of alterations of volcanic ash in the sea water, or from submarine siliceous springs which may have issued throughout Monterey time from the former areas of volcanic eruptions.[35] There is no physical evidence to support these theories, except that the upper Monterey generally becomes more cherty and siliceous in the vicinity of Tranquillon Mountain. This is generally true of the lower Monterey also, which consists predominantly of cherty shale in that vicinity. Aside from the Franciscan, the Tranquillon is the only volcanic series within the mapped area and the Monterey the only formation containing appreciable amounts of volcanic ash.

The Monterey shale is believed to be essentially a chemical deposit, made up predominantly of silica. Although much of this was deposited organically in the form of diatom tests, the silica itself must have had a chemical origin, and that not used by organisms must have settled out from colloidal suspension and deposited in much the same manner as calcium carbonate does to form limestone. The lower Monterey contains an appreciable amount of limestone as beds averaging about a foot in thickness. A thick basal limestone as much as 150 feet thick forms the base of the Monterey in the canyon of El Jaro Creek. Although some of the calcium carbonate making up the limestone was deposited orginally by foraminifera and calcareous algae, most of it is of chemical origin.

[35] Taliaferro, N. L., The relation of volcanism to diatomaceous and associated siliceous sediments: Univ. California Dept. Geol. Sci. Bull., vol. 23, no. 1, pp. 1-56, 1933.



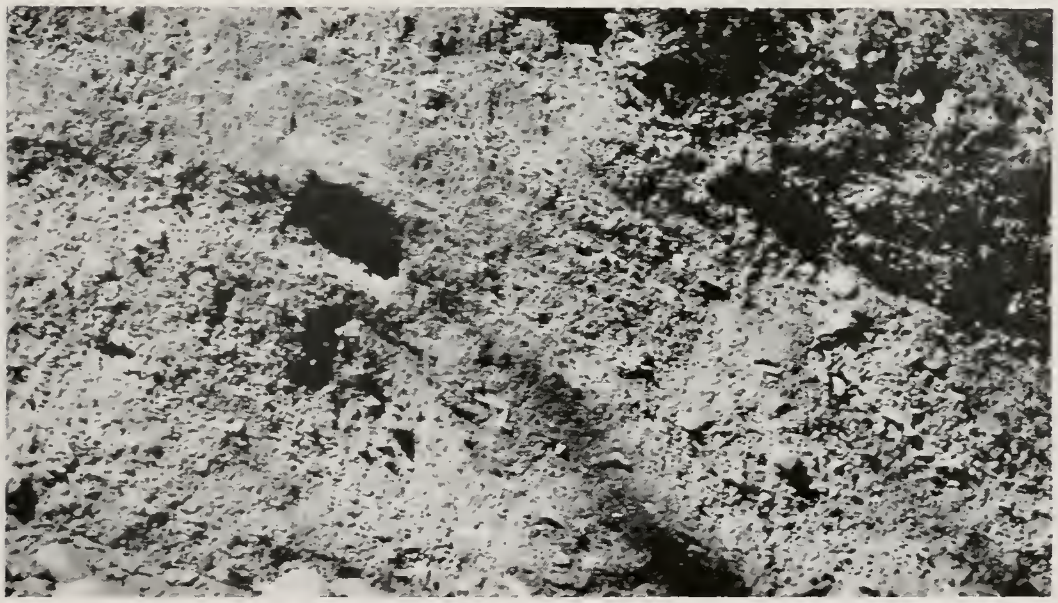
PLATY PORCELANEOUS SILICEOUS SHALES

Member F, upper Monterey, near mouth of Alegria Canyon.

A, THIN-BEDDED FORAMINIFERAL SHALE
Member D, lower Monterey shale, in Alegria Canyon.

B, CHERTY SILICEOUS SHALES
Member E, upper Monterey shale, near mouth of Jalama Canyon.

A. VIEW WEST ALONG COAST FROM MOUTH OF CUARTA CANYON
Sisquoc shale exposed along beach; Monterey shale forms hills back of coastal terrace. Derrick of Wilshire Oil Company well No. "Hollister" 1 on sea cliff.



B. TYPICAL EXPOSURE OF PASO ROBLES TERRESTRIAL CONGLOMERATE
7 miles east of Santa Ynez. Made up largely of shale pebbles.

TAR-SOAKED CONGLOMERATE AND SANDSTONE
Near top of Monterey shale, east of Alegria Canyon half a mile from beach.

Calcium phosphate was deposited in the form of collophane which makes up the buff-colored blebs and lenticular laminae in soft, dark brown organic shales. This type of shale, known as phosphatic or ''buff and brown'' shale in oil fields, is characteristic of the lower Mohnian and Luisian portion of the lower Monterey.

The Monterey shale is remarkable for its enormous quantities of silica. The siliceous rocks of the Monterey and part of the overlying Sisquoc formation are of three types, as recognized by Bramlette,[36] all of which are finely laminated and grade into one another: (1) diatomite (soft, white, ''punky,'' lightweight, porous); (2) porcelaneous shale (hard, brown, white-weathering shale with platy fracture); (3) cherty shale (very hard, brittle, vitreous, black, brown, gray, to white opaline shale with close sub-platy to conchoidal fracture; contains laminae or thin layers of black to brown chalcedonic chert [flint]; commonly minutely contorted, brecciated and recemented by veinlets of secondary opal or chalcedony).

Porcelaneous and cherty shale are characteristic of the upper Monterey, and occur locally in the lower Monterey. The diatomite is characterictic of the lower Sisquoc formation in some areas, but is also locally interbedded in the siliceous shales of the upper Monterey.

Considering the areal extent of the Monterey shale in California, it is difficult to postulate where such a great amount of silica could have originated. Many theories have been proposed, and these are thoroughly discussed by Taliaferro[37] and Bramlette.[38] The inorganic theory as advanced by Taliaferro[39] has already been discussed. The organic theory postulates that the hard siliceous shales were formed by alteration of organically deposited diatomite by deformation,[40] or by compaction from overlying sediments.[41] However, neither the source of the siliceous sediments nor the process by which they were formed can be accounted for satisfactorily by these theories, and there is little direct evidence to support them. How the enormous quantity of silica was made available, or exactly how it was deposited to form siliceous shales, is not known.

The normal sequence of the three types of siliceous sediments is the order given, cherty shale making up the lower part of the upper Monterey, and grading upward through porcelaneous shale into diatomite. Much of the contact between the siliceous shale and diatomite is sharp and easily mappable. Detailed mapping shows that the three types are not at the same position in the section at all places; in some localities they are interbedded. From these relationships it is concluded that these three types of siliceous sediments are of primary origin and that they are facies, as suggested by Regan and Hughes,[42] determined by local conditions of deposition, the relative amount of free silica deposited, and the amount deposited by organisms.

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[36] Bramlette, M. N., Monterey formation of California and origin of its siliceous rocks: U. S. Geol. Survey Prof. Paper 212, pp. 1-55, 1946.

[37] Taliaferro, N. L., The relation of volcanism to diatomaceous and associated siliceous sediments: Univ. California Dept. Geol. Sci. Bull., vol. 23, no. 1, pp. 1-56, 1933.

[38] Op. cit.

[39] Op. cit.

[40] Arnold, R., and Anderson, R., op. cit.

[41] Bramlette, M. N., op. cit.

[42] Regan, L. J. Jr., and Hughes, A. W., Fractured reservoirs of the Santa Maria district, California: Am. Assoc. Petroleum Geologists Bull., vol. 33, no. 1, pp. 32-51, 1949.

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The Monterey shale is notable for its unusually large amount of organic debris, composed largely of remains of microscopic plant and animal life. The highly siliceous content of the marine waters following eruption of the Tranquillon volcanics apparently brought about a condition favoring unusually prolific development of one-celled plants such as diatoms. These were produced in such enormous quantities, especially during late Monterey deposition, that their siliceous tests accumulated to form thick deposits of impure to nearly pure diatomite, making up a large percentage of the siliceous shales of the Monterey. Along with the diatom debris but in lesser amounts were deposited siliceous remains of animals, such as tests of radiolaria and arenaceous foraminifera, and sponge spicules. Calcareous tests of foraminifera are extremely prolific only in the lower Monterey, and tests of arenaceous foraminifera are abundant in both members. The former are extremely abundant in some layers, especially in the phosphatic shales and thin limestone beds. Chitinous remains of fish scales are abundant throughout the Monterey. Molluscs are rare except for mud-pectens (*"Pecten" peckhami*) and other small thin-shelled pelecypods.

Besides the remains of organic life the Monterey shale contains a great amount of organic matter in the form of hydrocarbons or bituminous material. Where unweathered the Monterey shale is generally impregnated with this material, which gives the characteristic bituminous odor when freshly broken and imparts a dark brown color to the sediments. Where exposed, this organic matter leaches or oxidizes so that the rocks become light colored or even white. It is most abundant in the upper Monterey, which produces practically all the oil at Lompoc and Zaca oil fields. This organic matter was probably deposited in water too deep and too far below wave and current action to be subject to oxidation, and consequently became buried and preserved in the fine sediments of the Monterey.

A characteristic feature of the Monterey shale is the rhythmic bedding, which is described in detail by Bramlette.[43] This feature is most apparent in the siliceous shales, in which the rhythmic beds are 1 inch or 2 inches thick and consist of hard porcelaneous or cherty shale alternating with layers of softer somewhat more clayey shale. Superimposed on this rhythmic sequence of beds is a series of fine laminae which likewise shows a definite alternation of layers that contain abundant siliceous or organic matter with those that contain less. These rhythmic laminae are believed to represent annual cycles of deposition.

Age. The lower Monterey and upper Monterey are mapped as lithologic units and the contact separating them is not necessarily a time horizon. The ages of the various sub-members west of Gaviota are already indicated. In the Santa Ynez Mountains the upper Monterey falls into the lower Delmontian stage and upper Mohnian stage (*Bolivina hughesi* zone), upper Miocene, and locally includes some lower Mohnian. The lower Monterey falls into lower Mohnian (*Baggina californica* zone); Luisian stage (*Siphogenerina collomi-Valvulineria californica* zone); Relizian stage (*Siphogenerina branneri* zone), middle Miocene; and uppermost Saucesian stage (*Uvigerina obesa* zone), uppermost lower Miocene.

[43] Op. cit., pp. 30-34.

Sisquoc Formation

The Sisquoc formation in southwestern Santa Barbara County consists of from 3000 to 5000 feet of diatomite and diatomaceous clay shale lying above the Monterey shale and below the Foxen and Careaga formations. The Sisquoc formation is exposed on both flanks of the Santa Ynez Range, on Burton Mesa, and throughout the Purisima Hills. The type locality is on the south side of Sisquoc River canyon near the mouth of Foxen Canyon, north of the area mapped, where the Sisquoc consists predominantly of fine sands.

The Sisquoc formation is best developed in the Purisima Hills, where it attains a thickness of nearly 5000 feet. The general sequence here is as follows:

Foxen claystone	
Conformity	
Gray-white poorly bedded diatomaceous claystone, with a predominant 200-foot layer of laminated white diatomite ("marker diatomite") at middle	1000± feet
Variations from light-gray massive to poorly bedded diatomaceous claystone with conchoidal, spheroidal, or splintery fracture, to cream-white well-bedded to massive impure diatomite; north of Lompoc field lowest exposed portion contains layers up to 6 inches of massive brown opaline chert; in eastern Purisima Hills lowest portion becomes massive to laminated white diatomite	4000± feet
Massive, semi-friable fine-grained brown sand, impregnated with tar	0-50 feet
Conformity	
Monterey—laminated diatomite and platy siliceous shale	

In the Burton Mesa area the Sisquoc formation is about 2300 feet thick and is similar in lithology to the Sisquoc of the Purisima Hills. The upper 300 feet is composed of nearly pure laminated white diatomite which is probably the equivalent of the marker diatomite of the Purisima Hills. The remaining 2000 feet consists of diatomaceous claystone with splintery fracture, of which the lowest 700 feet becomes thin-bedded diatomaceous porcelaneous shale which grades downward into Monterey platy shale.

In the Santa Rita Hills and west along the hills south of Lompoc Valley the lowest 750 to 1000 feet of Sisquoc consists of soft, white, laminated, punky, almost pure diatomite. This is quarried extensively south of Lompoc. It generally grades downward into cherty shale of the underlying Monterey, but at several localities near the Santa Ynez River between Salsipuedes and Drum Creeks the base of the diatomite is marked by a few feet of sand locally, or by a thin layer of phosphatic pebbles, which can best be seen in a road cut near the mouth of Drum Canyon and on the Santa Rosa road east of Salsipuedes Creek. In the eastern Santa Rita Hills the Sisquoc diatomite overlaps the entire upper Monterey, thus indicating a local unconformity. The punky diatomite member of the Sisquoc grades upward into 750 to 1050 feet of massive cream-white diatomaceous claystone. This is unconformably overlain by the Careaga sand.

On the south flank of the Santa Ynez Range the Sisquoc shale, usually mapped as ''Santa Margarita'' shale, is exposed along the coast from Gaviota Beach to the mouth of Jalama Canyon. This is the youngest formation exposed on the coast. The maximum thickness, about 3200 feet, is exposed in the syncline north of Point Conception, where the section is as follows:

Top of section eroded	
Cream-white massive to poorly bedded somewhat punky silty diatomite with conchoidal fracture	800 feet
Light brownish gray massive to poorly bedded silty to diatomaceous claystone, crumbly, with spheroidal fracture	1400 feet
Light brownish gray well-bedded clay shale with splintery fracture, to laminated thin-bedded siliceous shale with platy fracture	1000 feet
Brown massive compact sandy siltstone, highly bituminous; disappears west of Cojo Canyon; between Cuarta and Gaviota Canyons contains lenses up to 75 feet of well-bedded breccia-conglomerate composed of Monterey cherty shale debris in tar-soaked sandstone matrix	0-100 feet
Disconformity	
Monterey porcelaneous shale	

Wells drilled throughout the San Rafael foothills encounter the Sisquoc formation below the Careaga sand. Cores indicate the Sisquoc here to consist of massive light-gray diatomaceous siltstone or shale grading upward into Careaga sand and lying unconformably on previously tilted and folded Monterey shale. The Sisquoc thins rapidly from Los Alamos syncline by successive buttressing out of the lower portion to an average thickness of about 300 feet in the northeastern part of the area. Here only the upper portion is present; it lies directly on Cretaceous or Franciscan rocks. The Sisquoc is exposed only at Birbent Canyon where it is upturned along the Little Pine fault. Here the Sisquoc consists of about 150 feet of white diatomaceous siltstone grading upward into Careaga sand and lying on serpentine.

The Sisquoc formation, like the underlying Monterey, is remarkable for the great amount of diatom tests and remains of other siliceous organisms which make up such a large part of it. Within the area mapped the Sisquoc consists of an admixture of diatom debris and clay, in varying proportions, deposited under an open sea. Tuffaceous material occurs in small amounts. Unlike the Monterey formation, silicified layers are rare in the Sisquoc except locally. Calcareous material and calcareous foraminiferal remains are scarce.

The lower 1000 feet of the Sisquoc formation is assigned to the Delmontian stage of upper Miocene, and the remainder to lower (and perhaps middle) Pliocene, on the basis of meager foraminiferal faunas found in wells, and also upon molluscan faunas found in the sandy facies at Foxen Canyon north of the area mapped.[44]

Foxen Claystone

The Foxen formation consists of about 800 feet of claystone lying conformably between the Sisquoc diatomite below and the Careaga sand above. Within the area mapped the Foxen crops out only in the western Purisima Hills in northern Lompoc quadrangle; the best exposure is at

[44] Woodring, Bramlette, and Lohman, op. cit., pp. 1350-1351.

the type locality 1½ miles south of Harris. From the Purisima Hills the Foxen dips under Los Alamos Valley and extends northward to Santa Maria Valley. The formation wedges out down the south flank of the Purisima Hills, and also eastward along strike on the north flank.

At the type locality the Foxen formation is about 800 feet thick and consists of light-gray massive claystone and siltstone containing fairly abundant diatom and foraminiferal remains. Northwest along the strike, just off the map, thin beds of buff sandstone containing phosphate pellets appear. The Foxen formation reaches its maximum development under Santa Maria Valley, where it attains a thickness of 2300 feet.

The relationship of the Foxen claystone to the Sisquoc diatomite is fairly sharp but conformable, although an unconformity on the south flank of the Purisima Hills is suggested by overlap of the uppermost Sisquoc by the Foxen. Throughout all exposures the Foxen grades upward into fine sands of the lower Careaga. Under the San Rafael foothills the Foxen formation may be represented by the thin transitional beds between the Sisquoc diatomite and Careaga sand, but is not recognized.

The restricted areal distribution of the Foxen claystone probably indicates that it was laid down under an embayment opening on the northwest into the ocean via Santa Maria Valley. Elsewhere the region mapped was apparently uplifted as indicated by the regional unconformity between the Sisquoc and Careaga formations.

On the basis of foraminiferal faunules the Foxen formation has been assigned to middle and upper Pliocene.[45]

Careaga Sand

The Careaga formation is a marine sand of upper Pliocene age lying conformably below the terrestrial Paso Robles formation and above Foxen, Sisquoc, or Monterey formations. The Careaga sand is present, either exposed or buried, throughout virtually all of the Santa Maria Basin with the exception of Burton Mesa. It crops out on both flanks of the Purisima Hills, north flank of the Santa Rita Hills, and southwest of Lompoc. It also crops out east of Santa Ynez where it extends beyond Los Olivos quadrangle and was mapped by Nelson [46] as the Fernando formation. Under Lompoc Valley fossiliferous Careaga sand is encountered below alluvium in water wells. It is deeply buried under upper Santa Ynez Valley and the San Rafael foothills, but crops out northwest of Birbent Canyon.

Like the Foxen claystone, the Careaga sand attains its maximum development under Santa Maria Valley, where it is some 1400 feet thick. Under Los Alamos Valley it is probably about 1000 feet thick. It is about 700 feet thick in the Purisima and Santa Rita Hills, and about 300 feet thick in the exposures east of Santa Ynez.

The Careaga sand is well exposed along the north flank of the Purisima Hills, especially at the type locality 2 miles south of Careaga station. Here the Careaga is about 725 feet thick and consists of two members, as follows:

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[45] Woodring, Bramlette, and Lohman, op. cit., 1354-1355.
[46] Op. cit., pp. 372-374.

Paso Robles formation
Conformity
Upper Careaga (Graciosa member)

Loose medium-grained gray-white sand	150± feet
Same as above, but with abundant well-rounded pebbles up to 2 inches in size of quartzite, porphyritic igneous rocks, and Monterey chert and shale; local occurrences of fossil pelecypod reefs	50± feet
Hard calcareous sandstone reef with abundant *Dendraster ashleyi; (Dendraster* reef*)*	0–10 feet

Lower Careaga (Cebada member)

Friable massive yellow-buff fine-grained sandstone	400± feet
Semi-friable well-bedded buff very fine-grained sandstone and minor interbeds of sandy siltstone	125± feet

Gradational contact
Foxen claystone

These two members are mappable throughout most of the Purisima and Santa Rita Hills. However, only the upper member is present in the Purisima Hills east of Zaca Creek and east of Santa Ynez. In the former area no fossils are present and it is possible that some of the sand mapped there as Careaga may belong to a younger formation. In the latter area the *Dendraster* reef marks the base of the Careaga sand.

The lower Careaga member is persistently fine and even grained, and was probably deposited under calm shallow waters of a protected bay similar to that in which was deposited the Foxen claystone, but more extensive. The lower Careaga was thus laid down under transgressing waters.

The upper Careaga member is a littoral or beach-sand deposit of varying lithology. The pebble bed at the base of this member is very persistent and indicates a widespread break in sedimentation. The basal *Dendraster* (sand dollar) reef indicates deposition under very shallow water. At Cebada and Purisima Canyons the upper Careaga contains very thick, irregular lenses of crossbedded coarse sand, often pebbly, calcareous, fossiliferous and hard. These were probably deposited as sand bars. The uppermost portion of the upper Careaga generally consists of as much as 300 feet of loose sand devoid of pebbles or fossils, which appears to be wind-blown dune sand. The upper Careaga sand was deposited under a widespread but very shallow embayment under which nearly the entire Santa Maria Basin was submerged. It represents the final stage of marine deposition in this area.

The relationship of the Careaga sand to the underlying Foxen claystone is conformable in the northwestern Purisima Hills. However where the Careaga sand lies on Sisquoc or Monterey formations, such as in the eastern Purisima Hills and Santa Rita Hills and eastward, the relationship becomes a widespread unconformity, for the most part with angular discordance. Under the San Rafael foothills and at Birbent Canyon the Careaga sand seems to grade downward into the Sisquoc diatomite, despite the absence of the Foxen claystone. The relationship of the Careaga sand to the overlying Paso Robles terrestrial beds is everywhere conformable, and locally difficult to determine; but the base of the latter is usually marked by the first appearance of white marl followed by clay.

The Careaga sand contains a large molluscan fauna. The following are the more important species occurring in both members. Those marked with an asterisk (*) are more abundant in the lower Careaga; those unmarked, in the upper Careaga:

Pelecypoda
- * Lucina cf. annulata
- Macoma cf. nasuta (Conrad)
- * Pecten (Lyropecten) cerrosensis Gabb
- * Pecten (Patinopecten) healeyi (Arnold)
- Pseudocardium cf. densatum (Conrad)
- "Venerupis" cf. hannibali
- * Yoldia cf. cooperii Gabb

Gastropoda
- Drillia graciosana Arnold
- Nassa moraniana Martin
- Olivella biplicata
- * Trochita radians Lamarck
- * Turritella gonostoma hemphilli

Echinoidea
- Dendraster ashleyi

On the basis of this fauna, Woodring[47] assigns the Careaga sand to upper Pliocene, correlative with the San Joaquin formation of San Joaquin Valley.

Paso Robles Formation

The Paso Robles formation is a series of terrestrial gravels, sands, and clays of probable uppermost Pliocene and lower Pleistocene age lying conformably on the Careaga sand. Like the Careaga sand, the Paso Robles formation is present throughout the Santa Maria Basin, with the exception of Burton Mesa. It is most extensively exposed in the San Rafael foothills where it attains a maximum thickness of some 4500 feet along the northeastern portion of these hills adjacent to the San Rafael Mountains. To the southwest it gradually thins to about 2000 feet in the vicinity of Los Alamos Valley, and to about 700 feet under Santa Rita Valley. It is absent under Lompoc Plain.

Poorly consolidated gravels, sands, and pebbly clays or silts constitute the Paso Robles formation. The gravels are usually cross-bedded, light gray, and in most areas are made up almost entirely of white shale pebbles derived from the Monterey shale. Sands are generally buff and well bedded, often pebbly. Clays and silts are massive to bedded, usually greenish but locally light reddish, and commonly pebbly.

There is no defined sequence in the Paso Robles formation, but in general clays and silts predominate in the lower portion and gravels in the upper, which becomes coarser toward the top.

In the San Rafael foothills the lower 2000 feet of Paso Robles generally consists of greenish-gray clays and minor white shale pebble gravels. West of Zaca Canyon a member of loose massive sand constitutes the lower 700± feet of Paso Robles. The upper portion of the Paso Robles is made up largely of gravels which become increasingly coarse toward the top of the formation. These gravels are made up of Monterey white shale pebbles, but adjacent to the Franciscan exposures of the San Rafael Mountains, Franciscan debris becomes increasingly abundant toward the top and makes up the entire content of the uppermost portion.

On the north flank of the Purisima Hills the Paso Robles formation consists of about 2000 feet of white shale pebble gravels with some clays in the lower portion. A prominent white freshwater limestone bed up to 3 feet thick occurs near the base in the basal clay member. A similar limestone bed, as much as 12 feet thick, known as Los Alamos limestone, occurs 1200 feet higher. Both these limestone beds contain small freshwater fossils.

[47] Woodring, Bramlette, and Lohman, op. cit., p. 1358.

SYSTEM	SERIES		MOLLUSCAN ZONES	STAGES: Molluscan	STAGES: Foraminiferal	FORMATIONS
QUATERNARY	REC.					ALLUVIUM
	PLEIST.	UPPER				ORCUTT
		LOWER		"Tulare" or "San Pedro"	•	PASO ROBLES
TERTIARY	PLIOCENE	UPPER	*Pecten coalingaensis*	"San Joaquin" or "U. Pico"	"A zone"	CAREAGA
		MIDDLE	*Turritella vanvlecki*	"Etchegoin" or "M., L., Pico"	"B zone"	FOXEN
		LOWER	*Astrodapsis peltoides* *Astrodapsis antiselli*	"Jacalitos" or "Repetto"	"C zone"	SISQUOC
	MIOCENE	UPPER	*Turritella carrisaensis*	"Neroly"	Delmontian	
			Echinarachnius gabbii	"Cierbo"	Mohnian	MONTEREY-UPPER
		MIDDLE	*Astrodapsis brewerianus*	Briones	Luisian	MONTEREY-LOWER
			Turritella ocoyana	"Temblor"	Relizian	
		LOWER			Saucesian	TRANQUILLON
						RINCON
			Turritella inezana	"Vaqueros"	Zemorrian	VAQUEROS

TERTIARY	OLIG.		*Turritella variata*	"Gaviota"	Refugian	ALEGRIA & SESPE
						GAVIOTA
	EOCENE	UPPER	*Turritella uvasana*	"Tejon"	"A-1 zone" "A-2 zone"	SACATE
						COZY DELL
			Turritella applini	"Transition"	"A-3 zone"	MATILIJA
		MIDDLE	*Turritella buwaldana*	"Domengine"	"B-1 to B-4 zones"	ANITA & SIERRA BLANCA —?—
			Galeodea susanae	"Capay"	"C zone"	(Absent?)
		LOWER	*Turritella meganosensis*	"Meganos"	"D zone"	
			Turritella pachecoensis	"Martinez"	"E zone"	
CRETACEOUS		UPPER	*Baculites chicoensis*	"Moreno" "Panoche" or "Chico"		JALAMA
		MIDDLE	*Desmoceras colusaensis*	"Horsetown"		(Absent?) —?—
		LOWER	"*Aucella*" *crassicollis*	"Paskenta"		ESPADA
JURASSIC		UPPER	"*Aucella*" *piochii*	"Knoxville"		
				"Franciscan"		HONDA
						FRANCISCAN

FIGURE 4. Chart showing age of formations in southwestern Santa Barbara County.

In the vicinity of Santa Rita Valley the Paso Robles consists of clays and gravels with several lenses of loose, windblown sand.

Orcutt Sand

The Orcutt formation ranges from less than a foot to 150 feet in thickness. It consists of nonmarine sand and gravel resting discordantly on the Paso Robles and older formations, and has been assigned to middle or upper Pleistocene. The type area is on the north flank of the Casmalia Hills west of Orcutt, north of the area mapped.

The Orcutt formation is extensively exposed in the vicinity of Lompoc Valley and Burton Mesa, and on top of the western Purisima Hills. In these areas it reaches a maximum thickness of 150 feet and consists of loose, medium-grained massive light-buff sand, probably deposited by wind blowing from the ocean beach to the west. The top of this sand is locally indurated by iron oxides into hard reddish-buff sandstone. The basal portion contains numerous well-rounded pebbles of quartzite, acidic igneous rocks, and Monterey chert and shale.

The Orcutt formation lies unconformably on older formations which have been previously folded, but is itself only gently tilted toward Lompoc and Santa Rita Valleys. It is tilted as much as 25° in the latter.

Terrace Deposits

In the Santa Ynez Valley and along valleys of the main streams are several stream-laid terrace gravels, some as much as 75 feet thick. In the Santa Ynez Valley the oldest and most extensive is tilted as much as 15° and may be the equivalent of the Orcutt formation farther west. This can best be seen on the road east of Solvang. Several younger terraces are prominent along the course of the Santa Ynez River.

Along the coast are terrestrial gravels apparently deposited on the wave-cut terraces. The low coastal plain which extends back to about two miles from shore is covered with stream-laid cobble-gravel, silt and sand as much as 75 feet thick. On the highway 1 mile west of Gaviota and also at Alegria Canyon, the basal portion contains fossiliferous beach sand. Small remnants of higher, elevated terrace deposits are found locally along the coast.

Alluvium

All stream-laid valley fills of Recent age are mapped as alluvium, which consists of unconsolidated loamy clays, silts, sands, and gravels, totaling as much as 170 feet in thickness.

The thickest and most extensive alluvial fill underlies Lompoc Plain. Water-well logs indicate that the upper 120 feet of alluvium on this flatland consists of sand and clay and minor amounts of gravel, and the lower 50 feet of water-bearing gravel. J. E. Upson [48] has prepared a subsurface map and cross-sections based on logs of water wells drilled in Lompoc Plain, which show that the upper 120-foot member underlies the entire plain, but that the lower 50-foot gravel member is present mainly in the northern portion, and in the extreme eastern and western portions is restricted to the vicinity of the Santa Ynez River channel. It is interest-

[48] Upson, J. E., Thomasson, H. G. Jr., and others, Geology and water resources of Santa Ynez River valley, Santa Barbara County, California: U. S. Geol. Survey duplicated rept., pls. 507, 508, June 1947. (Final report in press.)

ing to note that throughout the areal extent of this gravel the base is approximately 170 feet below the ground surface, and is consequently below sea level under much of Lompoc Plain, and even extends out to sea for an unknown distance beyond the mouth of the Santa Ynez River. This condition indicates subsidence during Recent time, or as Upson [49] believes, a rise of sea level following the late Pleistocene Wisconsin glacial period.

Between Lompoc and San Lucas bridge the alluvium along the Santa Ynez River floodplain is similar to that of Lompoc Plain but thinner, the upper member being about 40 feet thick, and the basal gravel member about 25 feet thick.

In upper Santa Ynez Valley, Los Alamos Valley, and level-bottomed canyons of the San Rafael foothills the alluvium is indistinguishable from terrace gravels and the Paso Robles formation, but contains considerable water-bearing gravel.

The alluvium which fills flood-plains of the major streams of the Santa Ynez Mountains and Purisima Hills is less than 100 feet thick, and consists mainly of loamy silt with minor amounts of sand and gravel. Along the coast this alluvium extends below sea level and out to sea beyond the mouths of the canyons.

STRUCTURE

Southwestern Santa Barbara County comprises parts of four major structural provinces. These are, starting from the south: (1) Santa Ynez Mountain uplift; (2) Lompoc lowland; (3) Los Alamos syncline; and (4) San Rafael Mountain uplift.

The Santa Ynez Range is made up of a very thick Cretaceous-Tertiary sedimentary section uplifted along the Santa Ynez fault and by geanticlinal folding.

The Lompoc lowland is an area of low relief, comprising Burton Mesa and Lompoc Valley, which wedges out eastward through Santa Rita Valley and lower Santa Ynez Valley. This lowland wedge is in part structurally synclinal but is regionally a "high", in which the Franciscan basement is relatively close to the surface and covered by a thin, little-disturbed sedimentary section. This thin-blanketed wedge separates the thick-blanketed Santa Ynez Mountains on the south from the thick-blanketed Los Alamos synclinal area on the north.

Los Alamos syncline is a deep structural downwarp traversing Los Alamos and upper Santa Ynez Valleys. It is developed where the Tertiary-Quaternary section of Santa Maria Basin attains its maximum thickness. This trough is flanked by the Purisima Hills on the south and the San Rafael foothills on the northeast, both of these being anticlinal uplifts developed where the sedimentary section thins rapidly from the deep synclinal trough.

The San Rafael Mountains have been uplifted largely by faulting along the southwestern base.

Nearly all axes of folds throughout the region mapped trend slightly north of west, indicating crustal shortening at right angles to that trend. This shortening apparently resulted from a regional stress system of compressive forces acting from a north-northeast south-southwest direction.

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[49] Upson, J. E., Late Pleistocene and Recent changes of sea level along the coast of Santa Barbara County, California: Am. Jour. Sci., vol. 247, no. 2, pp. 94-115, 1949.

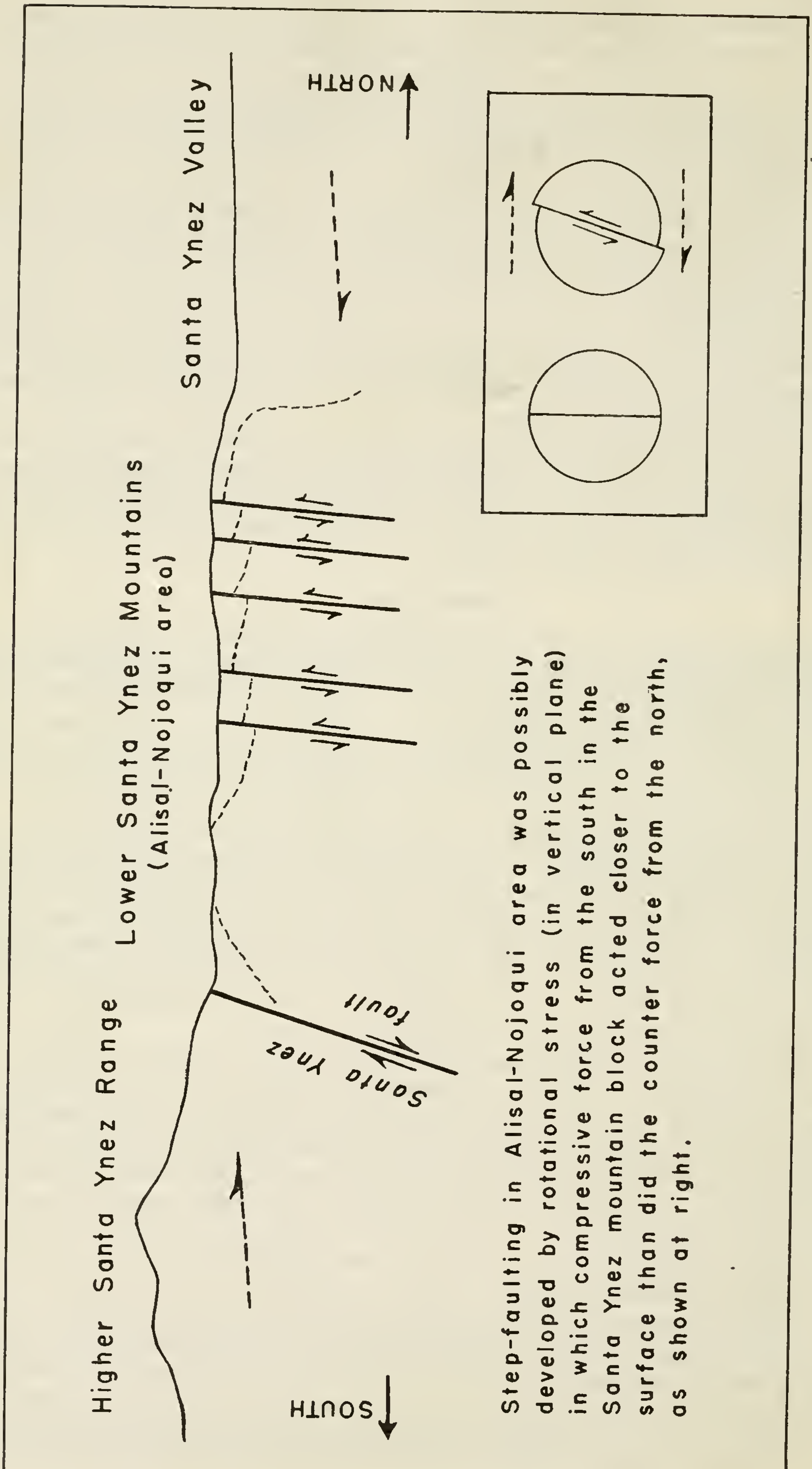

FIGURE 5. Tectonics of step-faulting in Alisal-Nojoqui area, Santa Barbara County.

The forces may have been directly opposing, but oblique-slip movement along many of the eastward trending faults in the Santa Ynez Mountains suggests a local counter-clockwise rotational force.

The various sedimentary provinces within the region mapped have reacted in various ways to the regional stress. Synclinal deeps such as Los Alamos syncline have resisted compression. This is true also of regional "highs" such as the Lompoc lowland, indicating that the Franciscan basement resisted compression. Areas of least resistance and greatest deformation are those in which the sedimentary section thickens or thins between these two extremes.

Santa Ynez Mountains

The western Santa Ynez Mountains consist of a northern and a southern structural block separated by the eastward-trending Santa Ynez-Pacifico fault zone.

Southern Structural Block

The southern structural block comprises the higher Santa Ynez mountain range extending eastward from Gaviota Canyon, and also the low ridge extending westward through the hills south of Jalama Canyon.

The higher Santa Ynez mountain range is a block consisting of a southward-dipping homocline in a very thick Cretaceous-Tertiary sedimentary series uplifted along the Santa Ynez fault on the northern base. The crest of this range is essentially a strike-ridge trending parallel to the Santa Ynez fault at a distance of about $1\frac{1}{2}$ miles south of it. This mountain block is abruptly terminated on the west by the south branch of the Santa Ynez fault extending from Gaviota Pass southwest to the mouth of Alegria Canyon. Gaviota Gorge is an antecedent canyon cutting through the extreme western portion of this uplifted block.

The low mountain ridge extending from Las Cruces westward to a point south of Jalama Canyon is a structural block similar to that of the higher Santa Ynez Range. It consists of a southward-dipping homocline in a slightly thinner Cretaceous-Tertiary sedimentary section, and is uplifted on the north along three faults, namely, the Santa Ynez (north branch), Gaviotito, and Pacifico faults. The crest is likewise a strike-ridge, but is broken at Santa Anita Canyon by the Pacifico fault. This homoclinal block in part forms the south flank of the Pacifico anticline which comes into it from the northwest at Santa Anita Canyon, and also the south flank of the Jalama anticline, coming in from a similar direction at Jalama Canyon.

Northern Structural Block

The northern structural block of the western Santa Ynez Mountains takes in that portion lying north of the Santa Ynez-Pacifico fault zone, including the Santa Rosa Hills, Santa Rita Hills, and Tranquillon Mountain ridge. The stratigraphic section of this northern block is about the same as that of the southern block, but is considerably thinner, and broken by six, possibly seven unconformities, indicating that the area was subjected to that many periods of deformation, uplift, and erosion. Consequently the structure is extremely complex. Details are shown on the areal geologic map and cross-sections. In general, the structure is one in which numerous minor folds, trending roughly N. 75° W., are developed in the Miocene formations, on the whole amounting to an anticlinorum. The older formations are compressed into several large folds with a similar trend, but these formations dip regionally to the south so that successively older formations underlie the Miocene from south to north.

The structure of the San Lucas-Wons Canyon area is that of a homocline in Lower Cretaceous and Eocene sediments dipping steeply north. These sediments are unconformably overlain by the Monterey shale, which in general dips away from them on both sides. The southwestern contact is possibly a fault contact, but evidence is not conclusive. It is therefore mapped as an unconformity like the northern contact.

Santa Ynez Fault System

The Santa Ynez fault and lesser faults associated with it constitute an active fault system of great magnitude, movement along which is largely responsible for the uplift of the Santa Ynez Mountains. From Gaviota Pass the Santa Ynez fault has been traced eastward continuously along the northern base of the high Santa Ynez mountain range for more than 65 miles into Sespe Canyon, Ventura County. The south block is up along the entire course and the throw amounts to several miles. Westerly from Gibraltar Dam the fault dips steeply south; farther east it becomes vertical; at Matilija Canyon it dips north.

The Santa Ynez fault is marked by a zone of gouge and crushed rock, often several hundred feet wide. The fault is well expressed topographically, as it in most places forms the base of the steep north slope of the Santa Ynez mountain front. It is generally marked by a topographic depression between this mountain front and the lower hills to the north, and is locally followed by streams emerging from the Santa Ynez Mountains.

A component of horizontal or lateral movement along all members of the Santa Ynez fault system in which the south block has moved relatively eastward, is strongly suggested by topographic, structural, and stratigraphic relations. West of Gaviota Pass the Santa Ynez fault divides into several faults of relatively small magnitude, all having the same trend and movement as the main Santa Ynez fault. The Pacifico fault is part of the Santa Ynez fault system.

From regional mapping it is concluded that the Santa Ynez fault system is a deep-seated zone of recent activity, trending eastward for a total distance of more than 80 miles. Oblique-slip movement of great magnitude has taken place along this zone; the southern block has been uplifted to form the Santa Ynez Range and has moved eastward relative to the northern block.

Santa Ynez Fault. Within Los Olivos quadrangle east of Quiota Canyon the Santa Ynez fault is composed of two closely spaced faults. The southern of these is the main Santa Ynez fault, which brings Eocene and Upper Cretaceous of the Santa Ynez mountain block on the south against Rincon-Vaqueros-Sespe on the north. At Wons Canyon this fault dips as low as 15° S., but to the east and west the dip steepens to near vertical. The northern fault is vertical and follows a straight course, bringing Rincon-Vaqueros-Sespe on the south in contact with Monterey shale (which lies directly on the Espada formation and serpentine at San Lucas and Wons Canyons) on the north. Between Quiota Canyon and Gaviota Pass the Santa Ynez fault is a single fault which brings the Jalama formation on the south against Rincon shale on the north, with a throw amounting to about 2 miles.

Throughout Los Olivos quadrangle the Santa Ynez fault shows some, though not conclusive, evidence of a horizontal or lateral component of movement, the south block having moved relatively eastward. Such movement, in which the block opposite the observer moved relatively to the left, is termed left-lateral displacement by Hill.[50] Topographic evidence of lateral movement on this fault is suggested by so-called "rift" topography along its course; that is, a general topographic depression locally followed by streams and marked by notches through hills crossed by the fault. Such topography is characteristic of recently active strike-slip and oblique-slip faults in California. Evidence for left-lateral movement along the Santa Ynez fault is indicated by offsetting of some canyons emerging from the north slope of the Santa Ynez Range, such as Quiota Canyon, which follow the fault always in a westerly, never an easterly, direction, before resuming their northward course. Structural evidence of left-lateral movement is suggested by the intersection of folds in the northern block always from a northwesterly, never a northeasterly direction, indicating left-lateral horizontal drag. Near-horizontal grooves have been found in the fault gouge, where it is exposed on Highway 101 near Gaviota Pass, and also in a minor parallel fault-plane on the old highway half a mile east of Gaviota Pass. Stratigraphic evidence of left-lateral movement along the Santa Ynez fault is suggested by the great difference of the stratigraphic section on either side of the fault at San Lucas and Wons Canyons. The mountain block on the south is made up of at least 15,000 feet of Upper Cretaceous, Eocene, Oligocene, and lower Miocene sediments, which do not appear on the northern block where Monterey shale directly overlies Lower Cretaceous or Upper Jurassic, but which are present west of Quiota Canyon. This stratigraphic anomaly may be explained by a great amount of left-lateral strike-slip displacement along the Santa Ynez fault.

Santa Ynez Fault, South Branch. At Gaviota Pass the Santa Ynez fault divides in two, from which point the south branch extends southwestward to the ocean at the mouth of Alegria Canyon. Displacement decreases rapidly from Gaviota Pass and the fault supposedly dies out under the sea. This fault appears to dip about 60° N., and movement has been upward on the southeast side, although some apparent reversal of throw is indicated at Alegria Canyon. However, this condition may be due to possible left-lateral movement. A hot sulfur spring issues from the fault south of Las Cruces.

Santa Ynez Fault, North Branch. From Gaviota Pass the steep-dipping north branch of the Santa Ynez fault extends westward for about 6 miles. Movement was upward on the south side of the fault, the maximum displacement being about 5000 feet. Displacement decreases to the west and the fault becomes a south-dipping thrust which dies out into the overturned axis of the Pacifico anticline.

Pacifico Fault. About half a mile south of where the north branch of the Santa Ynez fault dies out the movement is taken up by the Pacifico fault. This is the largest fault west of Gaviota Canyon, trending from Agua Caliente Canyon west for about 10 miles to Jalama Canyon. Santa Anita Creek flows eastward for some 3 miles along this fault before turning south. The east-trending portion of Santa Anita Canyon is known as the Pacifico, from which this fault was named. Movement has been

[50] Hill, M. L., Classification of faults: Am. Assoc. Petroleum Geologists Bull., vol. 31, no. 9, p. 1670, 1947.

upward on the south side of the fault, which dips very steeply south, and attains a maximum throw of about 5000 feet at the upper Pacifico. Here it splits into two closely spaced faults, which die out toward the west into the Jalama Canyon anticline. A left-lateral component of horizontal movement along this fault is suggested by associated folds on the north side, which intersect it from the northwest.

At the head of Bulito Canyon immediately south of the Pacifico fault are three small cross-faults subsidiary to the Pacifico fault, each with right-lateral displacement. The Jalama sandstone bed between these faults strikes N. 60° E., which is anomalous to the normal easterly strike. This condition suggests that these are small fault blocks rotated counter-clockwise by probable left-lateral horizontal drag along the Pacifico fault.

Bulito Fault. South of the Pacifico fault is a small vertical strike fault referred to as the Bulito fault, traceable for about 3 miles. It is difficult to recognize as it is so nearly parallel to the beds, but is clearly indicated by partial repetition of the Cozy Dell and Matilija formations. Left-lateral displacement is suggested by offset contacts.

Gaviotito Fault. From the Pacifico fault in the Pacifico, the Gaviotito fault branches off and extends north of east for about 4 miles. It dips steeply, and the south block has been elevated and moved eastward relative to the north block, as indicated by offset contacts and the offsetting of the axis of the Pacifico anticline.

Cojo Fault. The Cojo fault is a small north-dipping thrust fault about 4 miles north of Government Point. It is traceable for about 2 miles and appears to dip about 45° N. Offset contacts suggest left-lateral displacement whereby this fault may be related to the Santa Ynez fault system.

Other Faults in the Santa Ynez Mountains

Cañada Honda Fault. Traceable from Point Pedernales for about 6 miles eastward up Cañada Honda, is the Cañada Honda fault. This fault dips steeply south, and has a maximum throw of about 3000 feet, which brings Jurassic, Cretaceous, and Eocene rocks on the south against Monterey shale on the north. The latter formation is tightly crumpled into numerous sharp folds which intersect the fault from a northwesterly direction. This relationship indicates left-lateral horizontal drag along the fault, the south block having moved relatively eastward as well as upward.

Santa Rita Faults. Some distance farther east, but in line with the Cañada Honda fault, are three small en echelon faults trending about N. 75° E. for some 3 miles in the Santa Rita Hills. These are the Santa Rita faults, similar to the Cañada Honda fault but of less magnitude. The largest brings Monterey shale on the south against Sisquoc diatomite on the north. Here the Monterey shale is tightly compressed into folds intersecting the fault at a sharp angle from the east. This condition, as well as offset contacts, indicate left-lateral horizontal movement along these faults as along the Cañada Honda fault.

Much of the intervening area between the Santa Rita and Cañada Honda faults is a line-up of tightly compressed small closed anticlines en echelon in the Miocene, and trending about N. 75° W. The Cañada Honda and Santa Rita faults and the intervening and associated sharp folds were developed along a zone of oblique-slip movement; the southern block moved upward and eastward relative to the northern block, in a manner exactly similar to the Santa Ynez fault system, but on a smaller scale.

Faults in Tranquillon Mountain Area. Near Honda School in Cañada Honda is a small fault that trends northeast for about 2 miles. Offset contacts indicate movement along this fault to be left-lateral, the southeastern block having moved relatively northeastward.

Between Cañada El Morida and Cañada El Jolloru are three minor vertical faults trending about N. 75° E.; upthrow has been on the south side, in each case.

Two very old faults have been found near Tranquillon Peak. A mile east of this mountain is a northwest-trending fault which brings Espada shale on the southwest against Gaviota standstone on the northeast. The Vaqueros and Tranquillon formations extend right over this fault, without being cut by it. This fault was therefore active after deposition of the Gaviota but before the Vaqueros was deposited. It is believed to extend about 2 miles in both directions from the portion exposed but is concealed by the Miocene formations. The other fault, half a mile southwest of the peak, trends eastward. It brings Espada shale on the south against Rincon shale on the north, but the Tranquillon rhyolite flow extends directly over it, unaffected. It is therefore younger than the Rincon and older than the Tranquillon in age.

Faults in Santa Rosa-Nojoqui-Alisal Hills. Just north of the Santa Rosa ridge is a steep, probable reverse fault that trends eastward for about 5 miles. Movement has been upward on the south side of the fault; maximum throw has been about 2500 feet. Left-lateral horizontal movement may have taken place, as suggested by the axis of the Santa Rosa anticline which intersects it from the southwest. South of Alisal ranch are three minor reverse faults that dip south.

Throughout much of the Santa Rosa Hills and Nojoqui-Alisal area are numerous steep normal faults, all upthrown on the north side. They are minor faults, more or less equally spaced; they show no evidence of horizontal movement, and no relationship to the folding in the area. These faults are difficult to account for, but a possible explanation is that they constitute a series of northward-tilted blocks caused by differential movement.

Refugio Fault. The Refugio fault extends from Tajiguas Canyon eastward for about 6 miles to Capitan Canyon. It is well exposed at Refugio Canyon where it causes repetition of the Vaqueros sandstone. Here it dips 52° N., being a normal fault with about 500 feet of maximum vertical displacement. A similar normal fault, with only 100 feet of throw, occurs farther west in the Gaviota sandstone at San Onofre Canyon.

Erburu Fault. A north-dipping normal fault known as the Erburu fault forms in part the northern limit of production at Capitan oil field. It is exposed on the east side of Corral Canyon in the excavation at the Shell Company No. "Covarrubias" 1-37 well, where it dips about 50° N. Thrusting has been from the north, as the flat-lying Rincon shale is turned up adjacent to the fault, so that the shale dips south. This anomaly may be the result of horizontal movement along the fault. Associated folding suggests that the south block moved relatively eastward. West of Corral Canyon the fault dies out into an anticline. To the east it is concealed by terrace deposits; but it may be the continuation of the fault exposed in Las Yeguas Canyon north of U. S. Highway 101, just east of the area mapped. At Corral Canyon the Erburu fault brings flat-lying Rincon shale on the south against north-dipping Monterey shale on the north.

Las Yeguas Fault. Las Yeguas fault is well exposed on the sea cliff 1 mile east of Capitan. It is a reverse fault dipping about 60° N., bringing Rincon shale on the north against Monterey shale on the south. Offset contacts indicate probable horizontal movement, the south block having been displaced relatively eastward.

Lompoc Valley and Burton Mesa

The structure of Lompoc Valley and Burton Mesa is very simple, compared to that of the Santa Ynez Mountains. Wells drilled thoughout this lowland area pass through a comparatively thin blanket of Orcutt, Careaga, Sisquoc, and Monterey formations probably aggregating not more than 4000 feet in maximum thickness, and then directly into Franciscan rocks. The structure of the Tertiary section under Lompoc Valley is apparently a flat, undisturbed but broadly warped synclinal area. Orcutt sand is exposed around the valley but water wells in the level portion of the valley encounter fossiliferous sands of the Careaga below terrestrial deposits at a depth of about 175 feet. Monterey shale is exposed over a large part of Burton Mesa, which is a broad anticlinal upwarp, and along the shore line northward from Surf. This upwarp comprises many gently undulating folds with axes trending on the average N. 75° W.

The Lompoc Valley-Burton Mesa area is apparently a broad, wedge-shaped area widening seaward, of Franciscan rocks whose structure is unknown, covered by a thin blanket of middle and late Tertiary and Quaternary sediments. This block was apparently stabilized by pre-Monterey orogenies so that it resisted deformation and uplift during the great Pleistocene orogeny, and therefore remained as a very slightly disturbed lowland area. It extends an unknown distance out to sea, but to the east wedges into the narrow Santa Rita and lower Santa Ynez Valleys, which geologically form a part of it.

Lompoc oil field is located on a large, broad, closed anticline developed along the northeast edge of the Lompoc lowland wedge. This fold is not exposed at the surface, but eastward it becomes part of the Purisima anticline which emerges from under the Careaga sand. Wells encounter Franciscan below the Monterey shale at a depth of about 3000 feet under the Lompoc anticline. The fold is asymmetrical, the south flank dipping 5° to 10°, and the north flank about 30°. The dip increases with depth on the north flank due to the great thickening of the Sisquoc formation down dip.

Santa Rita Valley and Lower Santa Ynez Valley

The structure of the Santa Rita and lower Santa Ynez Valleys is a broad syncline with Orcutt and Paso Robles formations exposed on the surface, and the axis trending about N. 75° W. This synclinal valley area is structurally the eastward extension of the thin-blanketed Lompoc lowland high, and has like it resisted Pleistocene deformation and uplift.

Purisima Hills

The Purisima Hills are structurally an anticlinal uplift developed in a thick late Tertiary-Quaternary section. This uplift has been formed along a belt where the section thickens northward from the thin-blanketed Lompoc-Santa Rita-lower Santa Ynez Valley high on the south, to the very deep, thick-blanketed synclinal trough on the north which follows Los Alamos and upper Santa Ynez Valleys. As a result of this condition the anticlinal structure of the Purisima Hills is generally asymmetric; the south flank dips gently, and the north flank dips steeply or is even locally overturned toward Los Alamos Valley.

The main axis of the Purisima anticline trends about N. 75° W. and roughly follows the crest of the hills. The structure is highest in the eastern Purisima Hills, where Monterey cherty shale is exposed in the core, and Sisquoc and Careaga formations on the flanks. Numerous minor folds with axes trending about N. 75° W. are developed in the Monterey shale exposed in this area. The highest of these appears to be the one north of Buellton where the Frank Buttram No. "Reuben" 1 well passed from Monterey shale directly into serpentine at 1400 feet. In the extreme eastern Purisima Hills the anticlinal structure in the Monterey shale is overlapped by the Careaga sand and later formations, but is believed to plunge eastward under Santa Ynez Valley. Southeast of the town of Santa Ynez another fold emerges and rises eastward beyond the area mapped. A well ("National Exploration Co.") drilled on this fold just east of Los Olivos quadrangle reportedly bottomed in serpentine below Monterey shale at 2665 feet.

The high portion of the eastern Purisima Hills plunges westward into a saddle at Cebada Canyon. From here the axis in the pre-Careaga formations extends westward and rises into the concealed Lompoc anticline of Lompoc oil field. However the axis in the Careaga sand does not conform to this fold, but extends northwestward and rises into a sharp secondary anticline which exposes Sisquoc shale north of Lompoc field. This fold, referred to as the western Purisima anticline is closed, partly overturned and perhaps thrust-faulted southward. Many wells drilled on this structure find that it dies out at depth into the north flank of the Lompoc anticline.

Faults in the Purisima Hills. The western Purisima anticline appears to be cut by a small thrust fault that dips north. Evidence of this fault is suggested by the highly sheared and brecciated condition of the Sisquoc diatomite along the south edge of the hills here, and also by a zone of shearing at 2200 feet in Union Oil Company No. "Purisima" 19 well. Farther southeast are two small thrust faults that dip north at Purisima and Cebada Canyons. The westerly of these dips 45° N. with about 75 feet displacement. The easterly appears to be steeper, with about 100 feet of movement.

All three of these minor thrusts line up and appear to have developed where the section thickens rapidly northeastward.

Los Alamos Valley and Upper Santa Ynez Valley

The structure underlying Los Alamos and upper Santa Ynez Valleys is a major synclinal trough, the axis of which trends about N. 65° W., and passes through the towns of Los Alamos and Los Olivos. This downwarp is referred to as the Los Alamos syncline and forms the axis of the Santa Maria structural basin through the mapped area. It is a true synclinal downwarp made up of a continuous series of sediments Miocene to Pleistocene in age, which total some 15000 feet in thickness.

Along this synclinal trough the warped depositional surface of the Paso Robles formation is still preserved in eastern Los Alamos Valley and eastern Santa Ynez Valley.

San Rafael Foothills

In the San Rafael foothills, an area of gentle uplift, the Paso Robles formation is exposed and much dissected by erosion. The structure comprises two major anticlines, separated by a shallow syncline. The westernmost anticline is the Zaca, a very extensive, closed fold whose axis trends about N. 60° W. for more than 12 miles. The Zaca oil field is at its highest portion. Surface dips are about 15° on the south flank, 5° on the north flank. The easternmost anticline is the San Marcos, whose axis trends about N. 50° W. across Figueroa Canyon for some 15 miles, of which 6 miles lies within Los Olivos quadrangle. Northeast of this anticline is a syncline whose northeast flank is largely concealed under the Little Pine overthrust. These two folds are believed to cancel each other on the northwest under the Little Pine overthrust near Figueroa Canyon.

Wells drilled throughout the San Rafael foothills find that the structure in the Careaga and Sisquoc formations conforms with the surface structure of the Paso Robles formation. However, that of the Monterey shale does not conform, but generally dips more steeply to the southwest as it is overlapped from southwest to northeast by the Sisquoc, at least under the Zaca anticline. Local folds also complicate the Monterey structure so that details are not known. The Monterey shale is underlain by Cretaceous (?) shale and sandstone in this area. Wells drilled on the San Marcos anticline at Santa Aqueda Canyon pass from Sisquoc directly into Cretaceous (?).

San Rafael Mountains

The small portion of the San Rafael Mountains lying within Los Olivos quadrangle is composed of Franciscan rocks and sill-like masses of serpentine, striking due west to N. 60° W., and generally dipping steeply to the north. The Franciscan rocks may contain small sharp folds, but are so highly sheared and brecciated that it is not possible to work out structural details. In the northeast corner of Los Olivos quadrangle the Franciscan is overlain directly by Monterey shale that dips steeply to the northeast.

The Franciscan mass of the San Rafael Mountains has been thrust southwestward along the Little Pine fault over the Paso Robles formation of the San Rafael foothills. This fault dips from 25° to 38°NE at the surface. Southeast of the mapped area this thrust fault is traceable for some 20 miles along the base of the San Rafael Mountains. It extends about 8 miles through Los Olivos quadrangle and dies out into upturned Sisquoc and Careaga formations immediately northwest of Birbent Canyon.

GEOLOGIC HISTORY

Jurassic Deposition. The earliest geologic event recorded in southwestern Santa Barbara County is the rapid deposition under a widespread sea of the Upper Jurassic (?) Franciscan formation. This series of sands, muds, siliceous cherts and basaltic lava flows attained an unknown but tremendous thickness. Deposition of the Franciscan was followed by deposition of the Honda shale, at least in the Point Arguello area.

Late Jurassic Deformation. The earliest indication of diastrophism in southwestern Santa Barbara County is the highly sheared and brecciated condition of both the Franciscan and Honda formations, and the numerous serpentinized intrusions throughout the former. Neither formation, however, was metamorphosed. The Espada formation is not generally affected in this manner, indicating that the disturbance occurred after deposition of the Honda, and probably before deposition of the Espada shale. The shearing and brecciation were probably caused by tectonic forces, but may have been the result of numerous basic intrusions and their subsequent physical expansion caused by hydrothermal alteration to serpentine. The record is too obscure to determine whether or not the region emerged from the sea during this disturbance. The Franciscan formation was affected in the manner above described soon after deposition throughout the Coast Ranges belt of California northward from the Santa Ynez Range. This diastrophism occurred during very late Jurassic time and was probably in part synchronous with the great Nevadan orogeny.

Late Jurassic-Early Cretaceous Deposition. The Jurassic deformation was followed by continued subsidence of perhaps the entire mapped area below sea level. A great thickness of alternating muds and fine sands, the Espada formation, accumulated during the close of Jurassic and throughout early Cretaceous time. Plant life was abundant, as indicated by the great amount of carbonaceous matter in the sediments. Local intrusion of ultrabasic rocks may have continued during deposition of the Espada, as suggested by the local occurrences of serpentine in the lower portion of the Espada formation in San Lucas Canyon.

Middle Cretaceous Deformation (?). The middle Cretaceous record in the mapped area is not clear, as it is not definitely known whether or not this period is represented in the Espada formation. However the possible unconformity at the base of the Jalama formation suggests that the northern part of the Santa Ynez Range, and perhaps the area to the north, may have emerged during this time.

Late Cretaceous Deposition. During late Cretaceous time subsidence continued along the site of the Santa Ynez Mountains, which became the northern part of the Santa Barbara embayment. This sea received some 3000 feet of muds, silts, and sands which constitute the Jalama formation. The absence of this formation north of the Santa Ynez Mountains suggests that area was emergent during late Cretaceous time.

Early Eocene Deformation. The regional unconformity between the Cretaceous Jalama-Espada formations and the Eocene Anita shale (or Sierra Blanca limestone where present) along the northern portions of the Santa Ynez Mountains indicates this area to have undergone a period of emergence, uplift, and erosion during early Eocene time. This disturbance is apparently the local result of the great Laramide orogeny, active at the close of Cretaceous time. The local area affected includes not only the northern portion of the Santa Ynez Range, where its results can best be studied, but also what is now the Santa Maria Basin and the San Rafael Mountains. This entire affected area is referred to by Reed and Hollister [51] as the San Rafael uplift. It probably emerged during late Cretaceous or early Eocene time and developed as a broad, regional upwarp. The major portion remained emergent until early or middle

[51] Op. cit., p. 13, fig. 6.

Miocene. Its southern margin, the site of the northern Santa Ynez Mountains, appears to have undergone a regional tilt to the south. The Santa Barbara embayment was unaffected.

Eocene-Oligocene Deposition. From middle Eocene through early Oligocene (Refugian) time, what is now the Santa Ynez Mountains subsided continuously in the region of the Santa Barbara embayment, in which was rapidly deposited a continuous series of sands, silts, and clays making up the Anita, Matilija, Cozy Dell, Sacate, and Gaviota formations, which attained a total maximum thickness of about 7500 feet.

During late Oligocene (late Refugian) time sedimentation gradually exceeded subsidence in the Santa Barbara embayment so that it became filled with sediments, causing partial regression of the sea. Terrestrial sands and red silts of the Sespe formation were deposited in the eastern portion, which formed a level plain. The area to the west remained submerged under very shallow water, in which were deposited littoral sands of the Alegria formation. Maximum thickness of the Sespe-Alegria sediments amounts to about 2000 feet.

The sediments deposited during Eocene-Oligocene time were derived mainly from granite and metamorphic rocks, probably from an area to the east, as indicated by their mineral composition and the predominance of pebbles of granitic and quartzitic debris. Franciscan debris was deposited in only very minor amounts, although it makes up a large part of the Sespe conglomerate and red beds deposited in the Alisal-Nojoqui area along the southern border of the rising San Rafael uplift.

Oligocene Deformation. While the Sespe and Alegria formations were being deposited in the Santa Barbara embayment, the San Rafael uplift underwent renewed deformation, uplift, and erosion. This disturbance, the Ynezan orogeny, probably reached its climax at the close of Refugian or beginning of Zemorrian time. The San Rafael uplift, or at least that portion now occupied by Burton Mesa and the Purisima Hills, rose to a rugged area exposing the Franciscan, which became the source of the Sespe-Vaqueros conglomerates deposited along the southern border.

The effects of the Ynezan orogeny can best be studied along the northern Santa Ynez Mountains, where sediments deposited along the northern margin of the Santa Barbara embayment become involved. Here the Gaviota and older formations became compressed into broad gentle folds with axes trending slightly north of west, and near the site of Tranquillon Peak some faulting occurred. This is the earliest definite record of folding and faulting in the Santa Ynez Mountains. This deformation was accompanied by emergence, uplift, and erosion.

Early Miocene Deposition. In Zemorrian (early Miocene) time during or immediately following the Ynezan orogeny terrestrial sediments derived from the Franciscan San Rafael uplift were deposited in the Nojoqui-Alisal area. These make up the Sespe conglomerate and red beds of that area. Submergence of the entire northern Santa Ynez Mountain area under a shallow sea transgressing northward from the Santa Barbara embayment immediately followed. In this advancing sea was deposited coarse gravel, then sand, of the Vaqueros formation, followed by fine muds of the Rincon formation as the sea deepened in Saucesian (early Miocene) time.

The San Rafael uplift was not submerged during Zemorrian-Saucesian time but it contained at least one inland basin which received terrestrial sediments of the Lospe formation.

Early Miocene Deformation. In the very late Saucesian (late early Miocene) time another disturbance, the Lompocan orogeny, affected the San Rafael uplift, causing renewed uplift, deformation, and erosion. The Lompocan orogeny involved essentially the same portion of the Santa Ynez Mountains as that affected by the preceding Ynezan orogeny, especially the portion from San Julian Valley westward. Here folds developed during the former orogeny became further compressed during the latter and involved the Vaqueros-Rincon formations.

The Lompocan orogeny and its forerunner, the Ynezan orogeny, are extremely important in the geologic history of the mapped area and perhaps of California, as they brought about a great change in paleogeography. The Lompocan orogeny is especially significant as it was immediately followed by local volcanism, regional submergence, and a great change in sedimentation.

Early Miocene Volcanism. Near the end of Saucesian time the Lompocan orogeny was immediately followed by volcanic eruptions of rhyolite lava, agglomerate, and ash at the site of Tranquillon Mountain, and by local eruptions of basalt lava and agglomerate at the site of the Santa Rita Hills. These volcanic and pyroclastic rocks make up the Tranquillon formation and were probably erupted as the region subsided following the Lompocan orogeny.

Middle and Late Miocene Deposition. The Tranquillon volcanism was accompanied or immediately followed by submergence of the San Rafael uplift, so that throughout Relizian, Luisian (middle Miocene) and Mohnian (late Miocene) time the entire mapped area was under the sea which flooded a large part of California. In this widespread open sea deposition of clays continued in early Monterey time but in decreasing quantities as the nearby land areas became submerged. Calcium carbonate was deposited to form the limestones of the lower Monterey. The Monterey sea received enormous quantities of siliceous sediment, deposited either organically or chemically. All these fine sediments must have accumulated very slowly in the open sea at a depth below wave and current action.

Marine life, particularly single-celled organisms, flourished during Monterey deposition, and their remains make up a large part of the Monterey formation. Much organic debris settled to the bottom and, perhaps because of the great depth of the sea, was not oxidized. It consequently became buried with the fine sediments, to form petroleum and other bituminous matter.

The sea floor subsided at a more or less uniform rate and received an average of about 2000 feet of Monterey sediments. However, subsidence and deposition became unusually rapid along Los Alamos trough, which began to develop as a downwarp, and received at least 4500 feet of Monterey sediments.

Late Miocene Deformation. Deposition of the Monterey formation was followed by a local but important disturbance, the Rafaelan orogeny, which affected the area northeast of the Santa Maria-Los Alamos trough and part of the San Rafael Mountains in Delmontian time. The result of this orogeny is most evident in the Santa Maria Valley oil field, as indicated by the northward overlap of the Sisquoc formation upon the Monterey and Franciscan. A similar condition generally exists southeastward through the San Rafael foothills, as indicated by wells, from which it is evident that this area underwent emergence, uplift, and erosion by being tilted regionally to the southwest. Some local folding may have occurred. The Rafaelan orogeny thus has affected the old San Rafael uplift, but only the axial portion of it. Other areas throughout the region mapped were undisturbed, except for slight local uplift at the site of the Santa Rita Hills and southern Santa Ynez Mountains.

In the Santa Rita Hills the unconformity at the base of the Sisquoc formation and consequent overlap of the upper Monterey shale indicate this area to have undergone local uplift and erosion. Evidence that the earliest uplift along the site of the southern or higher Santa Ynez Mountains occurred during the Rafaelan orogeny is suggested by the breccia conglomerate containing Monterey chert pebbles at the base of the Sisquoc shale west of Gaviota Beach.

Late Miocene-Pliocene Deposition. The Rafaelan orogeny was followed by deposition of fine sediments of the Sisquoc formation during late Miocene and early Pliocene time. Subsidence and deposition were continuous and rapid along the Los Alamos trough, which received some 5000 feet of Sisquoc diatomaceous mudstone. Northeastward from this downwarp, the Sisquoc sea transgressed onto the San Rafael axis which gradually became buried by diatomaceous clay and silt.

During late Miocene (Delmontian) time, the sea between the Los Alamos trough and what is now the southern Santa Ynez Mountains received about 1000 feet of lower Sisquoc diatomite. This sediment is made up almost entirely of diatom tests, indicating a local condition extremely favorable for very rapid propagation of diatoms. The very low percentage of clastic material in this finely laminated diatomite indicates deposition in protected waters, and fish remains found in these sediments are mainly shallow-water species. The diatomite of the lower Sisquoc was apparently deposited in a shallow, protected area of the lower Sisquoc sea; sheltered perhaps by the local uplift developed during the Rafaelan orogeny along the site of the southern Santa Ynez Mountains which may have persisted through late Miocene time either as a very low island or peninsula, or more likely as a submarine ridge. South of this uplift, clay and minor amounts of siliceous sediment accumulated under an open sea.

During early Pliocene time, open seas probably existed throughout the mapped area, in which were deposited clay, silt, and diatom debris of the middle Sisquoc. Near the end of early Pliocene time, diatomite of the upper Sisquoc was deposited in the Purisima Hills-Burton Mesa area.

In middle Pliocene time, subsidence continued in at least the western portion of the Los Alamos trough, which received about 1000 feet of claystone of the Foxen formation. There is no record of deposition elsewhere in the mapped area during this time interval.

Late Pliocene Deformation. In late Pliocene time, following or perhaps accompanying deposition of the Foxen mudstone, most of the area mapped underwent a great regional disturbance, the Zacan orogeny, indicated by the widespread unconformity at the base of the Careaga sand. This is best seen in the eastern Purisima Hills where the Careaga sand laps over the eroded surface of the Sisquoc and Monterey formations. During the Zacan orogeny the entire region, with the exception of the Los Alamos trough and San Rafael foothill area, underwent widespread deformation, emergence, and erosion. Both the San Rafael and

Santa Ynez Mountains came into existence by emergence and uplift along lines of structural weakness which evolved into the present major faults in these ranges. The folds formed in the northern Santa Ynez Mountains during the Ynezan and Lompocan orogenies were further compressed, and the Monterey-Sisquoc formations became involved in many new folds with similar trends. The Burton Mesa and eastern Purisima Hills emerged as anticlinal uplifts.

Late Pliocene-Pleistocene Deposition. The Zacan orogeny was followed by submergence of the entire Santa Maria Basin, with the exception of Burton Mesa, in late Pliocene time, under a shallow embayment in which was deposited the Careaga sand. Subsidence and deposition were most rapid along the Los Alamos trough.

Toward the end of Pliocene time the Santa Maria Basin became filled with sediments, causing the sea to withdraw, and became a broad plain on which terrestrial sediments of the Paso Robles formation were deposited. These were derived from the rising San Rafael and Santa Ynez Mountains, and became increasingly coarse as these ranges grew during the Pleistocene.

The Paso Robles sediments were derived mainly from the San Rafael Mountains, and deposition of these alluvial sediments was especially rapid along the foot of this range where the formation attains a thickness of more than 4500 feet. It progressively thins away from this mountain front. This appears to be a case in which the weight of rapidly deposited sediments actually caused subsidence of the underlying platform.

Pleistocene Deformation. The increasing growth of the San Rafael and Santa Ynez Mountains culminated in the early Coast Range orogeny in the middle Pleistocene, when these ranges probably attained their present heights. This great orogeny affected the entire mapped area, causing further compression of folds formed by earlier orogenies, and the development of many other structures, in which the Careaga and Paso Robles formations were involved. The Purisima Hills and San Rafael foothills were formed during this disturbance by anticlinal folding.

The mountains and hills formed during the early Coast Range orogeny underwent intensive erosion which is referred to as the "first erosion cycle." This is described in detail under the section headed *Erosion Cycles.*

The late Pleistocene was a period of relative quiescence, during which the elevated areas were worn down to the late mature stage of erosion and sands of the Orcutt formation were deposited in Lompoc and Los Alamos Valleys, and terrace gravels in Santa Ynez Valley and on the coastal plain.

The region underwent renewed deformation and uplift in very late Pleistocene and Recent time when it attained its present topography. This disturbance is termed the late Coast Range orogeny; during this time the area underwent the "second erosion cycle," as described under *Erosion Cycles.*

The complex structure and resultant physiography of Santa Barbara County were developed by the series of diastrophic events starting with the early Miocene Ynezan orogeny and culminating with Pleistocene Coast Range orogeny, caused by a recurrent stress system of increasing intensity, these events together constituting the local effect of the Cascadian revolution.

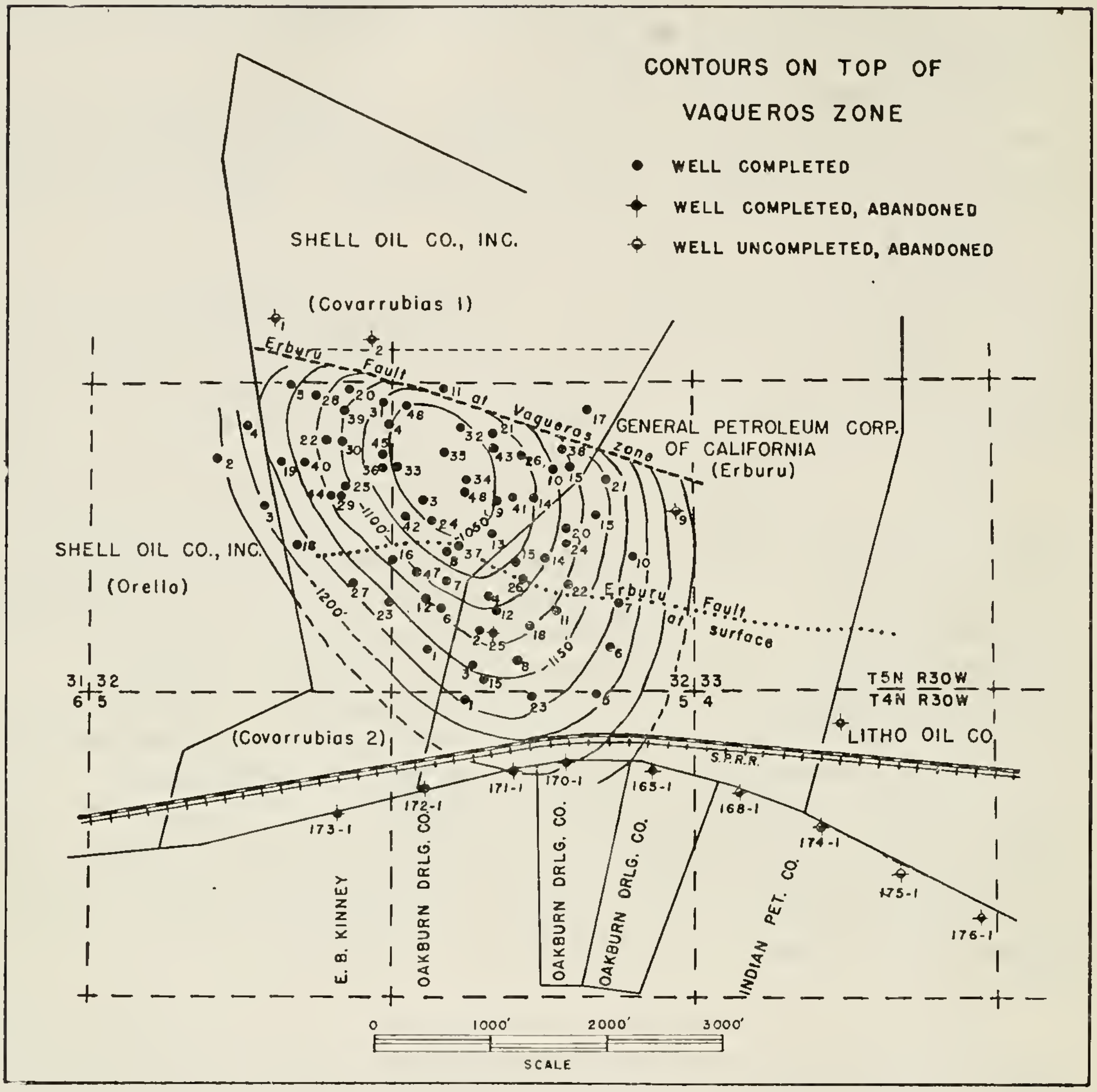

FIGURE 6. Structural map of Capitan oil field, Santa Barbara County.

MINERAL RESOURCES

Oil and Gas

Within the quadrangles mapped oil and gas have been found both in the Santa Barbara-Ventura Basin and in the Santa Maria Basin. The former yields high-gravity oil and considerable gas from sands of the Vaqueros, Sespe, and Eocene formations in closed structures along the southern coastal area between Capitan and Point Conception. The latter basin yields low-gravity oil from fractured siliceous shale of the Monterey formation in closed structures in the Purisima Hills and San Rafael foothills.

The intermediate areas between the two stratigraphic basins, namely the coast north of Point Conception, Santa Ynez Mountains, Santa Rita Hills, Burton Mesa, Lompoc and Santa Ynez Valleys, and southeastern Purisima Hills have failed to yield oil or gas. Throughout these areas are many closed anticlines exposing Monterey shale at the surface. Wells have been drilled on nearly all of these structures to test the lower Montrey shale and the underlying lower Miocene or Eocene sands, but all were dry holes, generally without showings. The results of exploratory wells drilled throughout these areas are indicated in the accompanying tables (see pp. 70-74).

Santa Barbara-Ventura Basin

Capitan Oil Field. The subsurface structure of the Capitan oil field is an anticlinal dome closed by drag against the north-dipping Erburu fault. This structure is not apparent on the surface, as the Erburu fault, which in part limits production on the north, crops out through the southern portion of the field and is paralleled on the north by a syncline in Monterey shale.

Since its discovery in 1929 the Capitan field has produced more than 11,000,000 barrels of 16° to 43° gravity oil from an area of 296 acres. Oil is produced from the Vaqueros sandstone at a depth of from 1000 to 1400 feet below sea level, and also from two zones in the upper Sespe: the Erburu 8 zone and Erburu 10 zone. The upper Sespe also contains a gas zone. Deeper drilling since 1945 has resulted in the discovery of large flowing wells, from the Covarrubias zone of the lower Sespe, and the Eocene zone at the top of the Gaviota-Sacate ("Coldwater") formation, which have greatly augmented the reserves of this field.

The Vaqueros zone was discovered by General Petroleum Corporation's No. "Erburu" 1 well in 1929. The Vaqueros sand produces from 100 to 600 barrels per day of 20° A.P.I. gravity oil.

The Erburu 8 zone of the upper Sespe was discovered by General Petroleum Corporation's No. "Erburu" 8 well, completed in January 1931 for 250 barrels per day of 40° to 42° gravity oil. This sand is 125 feet thick, is topped at 660 feet below the top of the Sespe, and produces 125 to 1000 barrels per day of oil. The Erburu 10 zone is 75 feet thick, is topped at 1000 feet below the top of the Sespe, and produces 100 to 600 barrels per day of 44° gravity oil.

The Covarrubias zone was discovered by Shell Oil Company's No. "Covarrubias" 1-35, completed February 1945 flowing 1375 barrels per day of 39° gravity oil from the interval 3355-3637 feet in the lower Sespe.

The Eocene or "Coldwater" zone was discovered by Shell Oil Company's No. "Covarrubias" 1-36, completed August 1945 flowing 520 barrels per day of 39° gravity oil from the interval 3805-3825 feet from uppermost marine Oligocene-Eocene (Gaviota or "Coldwater") sandstone.

As of January 1, 1948, Capitan field had 66 producing wells, of which 8 were flowing, 57 pumping, and 1 shut in. Cumulative production to that date was 11,897,000 barrels.

The geology of Capitan field is described in detail by Dolman [52] and Kribbs.[53]

Refugio Cove Area. At the mouth of Refugio Canyon is a large closed anticline in Monterey shale. Rincon shale is exposed on the crest of the fold at Refugio Cove. The first test well, Shell Oil Company No. "Rutherford" 1, drilled in 1928, found both Vaqueros and Sespe sands devoid of oil, and was drilled far into the Gaviota-Sacate ("Coldwater") formation which flowed dry gas and sulfur water. Since the deep test many other wells have been drilled on this closed structure, but none has obtained commercial production except Rothschild Oil Company No. "Orella" 1 which discovered the small Refugio gas field.

Refugio Gas Field. The Refugio gas field occurs on a small closed anticline in Monterey shale within the Refugio dome about a mile west of Capitan field. The discovery well, Rothschild No. "Orella" 1, drilled in 1946, flowed at an estimated rate of 5,000,000 cubic feet of gas per day from the Vaqueros sandstone at about 2500 feet. To date this field contains three gas wells.

Drake Area. Near Drake station, at the mouth of Cañada Santa Anita, is a syncline on shore and a supposed anticline off shore in Sisquoc shale with axial planes hading northward. The first test well, Western Gulf No. "Hollister" 1, drilled in 1928, drilled into the Vaqueros sandstone at 3088 feet and blew in out of control, producing an estimated rate of 25,000,000 cubic feet of gas per day. After the well was brought under control, it produced a few barrels of light oil and considerable salt water. The gas flow soon died down and after all attempts to shut off the water failed, the well was abandoned. Several other test wells were drilled on this structure, but all failed to obtain commercial production.

Point Conception Area. The north-dipping homocline in the Point Conception area is the possible north flank of a large off-shore anticline. This structure was tested in 1930 by Standard Oil Company No. "Gerber" 1 at Government Point. This well found some gas and salt water in the Vaqueros sandstone, was drilled through the Alegria, Gaviota, and Sacate formations and encountered good shows of light oil in tight sands of the Sacate (?). After all tests failed to obtain production, the well was abandoned.

Santa Maria Basin

Lompoc Field. Union Oil Company, which discovered Lompoc field in 1903, controls the major part of it and developed it in a conservative way until 1940. As of that date, the field produced 7,900,000 barrels of oil from 49 wells from an area of about 2200 acres. However, since 1942 this field has undergone renewed and more thorough development, due to

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[52] Dolman, S. G., Capitan oil field: California Div. Oil and Gas, Summary of Operations, California Oil Fields, Rept. 24, no. 2, pp. 15-26, 1938.

[53] Kribbs, G. R., Capitan oil field: California Div. Mines Bull. 118, pp. 374-376, 1943.

heavy demand for oil since the last war. Wells have been drilled at the rate of about two per month. The new wells completed have greatly increased production of the field, but the acreage has not been appreciably extended, as outpost wells are structurally too low and fail to obtain production. The field has produced 14,601,000 barrels of oil to January 1, 1948. On that date, production was from 77 wells, of which 6 were flowing, 67 pumping, and 4 shut in.

Lompoc field produces 15° to 24° A.P.I. gravity oil from fractured siliceous (only slightly cherty) shale of the upper Monterey, at depths from 1900 to 2200 feet below sea level. Production is from the western Purisima anticline which is closed and made up of at least two closed anticlines en echelon, separated by a syncline which is probably faulted near the axis. The geology of Lompoc field has been described in detail by Dolman [54] and Dibblee.[55]

Purisima Hills. Many test wells have been drilled throughout the Purisima Hills but with the exception of Lompoc field no commercial production has been obtained. Wells drilled in the central portion of the Purisima Hills were dry holes, as the structure of this portion is a saddle in the Purisima anticline. The eastern portion contains several closed anticlines exposing Monterey shale; these were tested, but the Monterey is here underlain by Espada or Franciscan and no oil was found. The south flank was tested by Richfield Oil Corporation No. "Skytt" 1 drilled to 6007 feet and abandoned without showings.

Wells drilled on the north flank of the Purisima Hills found the Sisquoc too thick to penetrate, although the Monterey was reached on an anticline across Santa Ynez Canyon where some heavy oil was found in Whittier Associates No. "Barham" 1. This well produced about 78 barrels of oil per day from fractured cherty shale of the Monterey at 4000 feet. No. "Barham" 2 was a dry hole, but No. "Barham" 3 obtained small production. These wells are not commercially productive.

Zaca Field. The discovery of Zaca oil field was made in 1942 by Tidewater Associated Oil Company, when its No. "Davis" 1 well was brought in pumping 294 barrels of 7° gravity oil including 37 barrels of distillate, 33 percent emulsion from Monterey cherty shale, at 4465 to 5956 feet. The well settled to 150 barrels per day, 7° gravity clean oil. Tidewater Associated Oil Company, which controls the field, has been developing it in an orderly way and to date has 10 producing wells. The field produces a moderate amount of oil averaging 8° gravity, which is so viscous that distillate must be injected in order to render the tarry oil fluid enough to pump out. As of January 1, 1948, Zaca field had produced a cumulative total of 358,000 barrels of 8° to 10° A.P.I. gravity oil from these wells.

The structure of Zaca field is a large closed anticline in the Sisquoc and overlying formations, and the oil is produced from fractured cherty shale of the Monterey which here unconformably underlies the Sisquoc. Detailed structure of the Monterey is not known, but is regionally a homocline dipping southwest, and the oil occurs in the cherty shale where it is overlapped by the Sisquoc.

[54] Dolman, S. G., Lompoc oil field, Santa Barbara County, California: California Div. Oil and Gas, Summary of Operations, California Oil Fields, Rept. 17, no. 4, pp. 13-19, 1932.
[55] Op. cit.

List of exploratory wells, southwestern Santa Barbara County.

Point Arguello Quadrangle

Map No.	Operator	Well	Year Comp. or Aband.	Depth	Geology	Geol. at Bottom	Remarks
A 1	Standard Oil Company	Shyvers No. 1	Ab. 1929	2661′	Top Lospe? ss & cg 2050′; Jf ss & sh 2400′	Jf	
A 2	Anglo-Calif. Oil Co.	Syndicate No. 2	Ab.	2100′	Top Jf 1080′?	Jf	
A 3	Anglo-Calif. Oil Co.	Syndicate No. 1	Ab. 1911	3515′	Top Lospe rd ss & cg 850′; Jf ss 1300′	Jf	
A 4	Prairie Oil & Gas Co.	Packard No. 1	Ab. 1930	5638′	Top Tt 1988′±; Lospe? 2192± Jf 2734±	Jf	
A 5	Gaviota Oil Co.	Moretti No. 1	Ab. 1929	2660′	Top Tm 150′; Jf (serp.) 2550′	Jf	
A 6	Bear Creek Oil Co.		Ab.	3500′			
A 7	Keystone Pet. Co.	True No. 1	Ab. 1929	3002′	Top Tm 200′; Jf (serp.) 2912′	Jf?	
A 8	Standard Oil Co.	Sudden No. 1	Ab. 1930	2828′	Top Tt 420′; Tr? 630′; Tv? 900′; Tcd? 1000′; Tma 1250′; Tan 1750′; Ke 2140′	Ke	
A 9	Independent Expl. Co.	Sudden No. 1	Ab. 1948	2513′	Top Tt 762′; Tr 1133′; Tcd? 1240′; Tma? 1823′; Ke 2304′	Ke	
A 10	Independent Expl. Co.	Sudden No. 2	Ab. 1948	2507′	Top Tt 873′; Tr 1280′; Tcd? 1358′; Tma? 1830′	Ke	
A 11	Union Oil Company	Sudden No. 1	Ab. 1930	2221′	Top Tr 978′; Tv 1080′; Eoc 1143′; K 1179′	K	

Lompoc Quadrangle

Map No.	Operator	Well	Year Comp. or Aband.	Depth	Geology	Geol. at Bottom	Remarks
B 1	Ohio Oil Company	Salsipuedes No. 1	Ab. 1930	4656′	Top Tr? 870′; Tv? 980′; Eoc? 1140′; Ke 1760′	Ke	
B 2	Barnsdall-Honolulu	Salsipuedes No. 1	Ab. 1947	1636′	Top Eoc? gy sh 385′; Ke blk sh 1518′	Ke	
B 3	J. T. Hurst		Ab. 1925	3515′		?	
B 4	Tidewater Assoc. Oil Co.	Leonis No. 1	Ab. 1930	4949′	Top Tt 600′; Tr 1490′; Tv 3300′; Ts 4500′; Eoc 4930′	Eoc	
B 5	Tidewater Assoc. Oil Co.	Sousa No. 1	Ab. 1940	3521′	Top Tr 400′; Tv 3190′	Tv	
B 6	The Texas Company	Petan No. 1	Ab. 1943	1741′	Top K 650′	K	Oil shows in Eoc. ss
B 7	The Texas Company	Petan No. 2	Ab. 1944	2111′	Top K 1100′	K	
B 8	Barnsdall-Honolulu	Petan No. 1	Ab. 1947	4985′	Top Tv 200′; Ts 380′; Tg 915′; Tsa 1290′; Tcd 2150′; Tma 4395′	Tma	
B 9	Fairview Oil Company	Beauterbaugh No. 1	Ab. 1939	3000′	Top Jf or Ke 1888′	Jf or Ke	
B 10	Union Oil Company	Burton No. 1	Ab. 1908	4455′	Top Tsq 140′; Tm 1920′?; Lospe? 3770′; Jf 4127′	Jf	
B 11	Union Oil Company	Nichols No. 1	Ab. 1910	4013′	Top Tm 2850′±?	Tm	
B 12	Sun-Bell	No. 1	Ab. 1939	2982′	Top Tm 2875′	Tm	Oil shows in Tm
B 13	A. E. Bell	No. 6	Comp. 1913	4997′			Small producer
B 14	A. E. Bell	No. 7	Ab. 1913	4516′			
B 15	Barca Oil Co.	No. 1	Ab.	?		Tsq?	
B 16	Union Oil Co.	Harris A-1	Ab. 1947	5572′	Top Tm 4850′±	Tm	
B 17	Barnsdall Oil Co.	"Pinal Dome 20"	Ab. 1911	4050′		Tsq?	
B 18	Barnsdall Oil Co.	"Western Union"	Ab. 1921	4807′		Tsq?	
B 19	Barnsdall Oil Co.	"Careaga 1"	Ab. 1932	5331′		Tsq?	
B 20	Barnsdall Oil Co.	"Western Union 87"	Ab. 1921	4014′		Tsq?	
B 21	General Pet. Corp.	"Esperanza 2"	Ab. 1911	4510′		Tsq?	
B 22	General Pet. Corp.	Los Alamos No. 1	Ab. 1946	6287′		Tsq	
B 23	General Pet. Corp.	"Esperanza-Los Alamos 1"	Ab. 1904	2150′		Tsq?	
B 24	Union Oil Co.	Purisima No. 19	Ab. 1930	4310′	Top Tm 2980′; Jf 3150′	Jf	Thrust fault at 1800′±
B 25	Union Oil Co.	Purisima No. 20	Comp. 1946	3933′	Top Tm 2367		
B 26	Union Oil Co.	Purisima No. 34	Ab. 1947	3750′			
B 27	Union Oil Co.	Purisima No. 47	Ab. 1947	3405′			
B 28	Union Oil Co.	Purisima No. 39	Ab. 1947	3535′			
B 29	Union Oil Co.	Purisima No. 46	Ab. 1947	3549′			
B 30	Union Oil Co.	Hill No. 1	Comp. 1903	2550′	Top Tm 2310±	Tm	Discovery well Lompoc field I.P. 225 B/D 19° oil
B 31	Union Oil Co.	Hill No. 21	Ab. 1947	3784′			
B 32	O. C. Field Gas Corp.	Union Annex No. 1	Comp. 1930	2997′	Base Tca 450; top Tm 2862	Tm	I.P. 600 B/D 22.5° 4% cut
B 33	Union Annex Oil Co.	No. 1	Ab. 1921	5108′	Top Tm 2800′?	Tm	
B 34	F. Love	Pacific Slope No. 1	Ab. 1911	4000′	Top Tm 2930?	Tm	
B 35	J. E. O'Donnel	Helen No. 1	Ab. 1939	4997′	Top Tm 2970′	Tm	Slight shows in Tm
B 36	L. B. O'Neil	Orena No. 1	Ab. 1932	3515′	Top Tca 1315′; Tf 2775′	Tf	
B 37	Italo Oil Co.	Koch No. 1	Ab. 1930	4975′	Tsq top to bottom	Tsq	
B 38	O. C. Field Gas Corp.	Santa Rita	Ab.	3358′			
B 39	Pet. Sec. Corp.	Los Alamos No. 1	Ab. 1934	4808′	Tsq top to bottom	Tsq	
B 40	Hancock-Pet. Sec. Corp.	Los Alamos No. 2	Ab. 1937	6530′	Tsq top to bottom	Tsq	
B 41	Tidewater Assoc. Oil Co.	Fox No. 1	Ab.	2985′			
B 42	Gen. Pet. Corp.	Fox No. 1	Ab. 1922	3742′	Top Tm 1556?	Tm	
B 43	Tidewater Assoc. Oil Co.	Buell Ranch No. 1	Ab. 1908?	1900′		Tm?	
B 44	Union Oil Co.	Crandall Government No. 1	Ab. 1948	4931′	Top Tm 3138′	Tm	
B 45	Union Oil Co.	Santa Rita No. 1	Ab. 1948	3600′	Top Tm 2510	Tm	

Los Olivos Quadrangle

Map No.	Operator	Well	Year Comp. or Aband.	Depth	Geology	Geol. at Bottom	Remarks
C 1	Jonata Oil Co.	Ward No. 1	Ab. 1945	1740′		Tsq	
C 2	Santa Barbara Oil Co.	Santa Ynez Val. & Dev. No. 2	Ab. 1906?	3545′?	Top Tsq 880′ Tm 3700	Tm?	
C 3	Richfield Oil Corp.	Skytt No. 1	Ab. 1945	6007′	Top Tsq 880′ Tm 3600± Ke-Jf 5710	Ke or Jf	
C 4	Frank Buttram	Reuben No. 1	Ab. 1928	2380′	Top Jf (serp.) 1400′	Jf	
C 5	Tidewater Assoc. Oil Co.	Buell Ranch No. 3	Ab. 1909?	2000′±		Jf?	Serpentine reported at 1100′
C 6	Santa Barbara Oil Co.	Santa Ynez Val. & Dev. No. 1	Ab. 1906?	2880′	Tm top to bottom?	Tm?	
C 7	Hydrocarbon Prod. Co.	Jones No. 1	Ab. 1922	1885′	Tm top to bottom	Tm	Tar sand reported at 900′
C 8	Union Oil Co.	Linus Buell No. 1	Ab. 1930	4589′	Top Tm-1 1240′; Ke or Jf 3320′	Ke or Jf	
C 9	Union Oil Co.	Buell No. 1	Ab. 1915	4572′	Top Tm 541′?	Tm?	Oil sand near bottom
C 10	Standard Oil Co.	Buell No. 1-C	Ab. 1925	4579′	Base Tm 4500′±?	Ts or Jf?	Shows of oil
C 11	Tidewater Assoc. Oil Co.	Buell Ranch No. 2	Ab. 1908	1900′±	Tm top to bottom	Tm	
C 12	Whittier Assoc.	Glenn Buell No. 1	Ab. 1945	1787′	Tm top to bottom	Tm	
C 13	Whittier Assoc.	Glenn Buell No. 3	Ab. 1945	2834′	Tm top to bottom	Tm	
C 14	Whittier Assoc.	R. Buell No. 1	Ab. 1945	962′	Tm top to bottom	Tm	
C 15	Whittier Assoc.	Barham No. 1	Comp. 1944	4847′	Top Tm 2480′	Tm	Plug. 3057 I.P. 15 B/D 14° 14% cut
C 16	Whittier Assoc.	Barham No. 3	Comp. 1946	6860′	Top Tm 2300′±	Tm	I.P. 70-100 B/D 26° 0.2% cut
C 17	Whittier Assoc.	Barham No. 2	Ab. 1944	3722′	Top Tm 2290′	Tm	I.P. 10 B/D water & trace of oil
C 18	J. I. Anderson & So. Cal. Pet. Corp.	Archambault No. 1	Ab. 1944	4765′	Top Tm 4010′	Tm	
C 19	J. I. Anderson & So. Cal. Pet. Corp.	Archambault No. 2	Ab. 1945	6016′	Top Tm 4200′±	Tm	
C 20	J. I. Anderson & So. Cal. Pet. Corp.	Archambault No. 3	Ab. 1945	1816′	Tm top to bottom	Tm	
C 21	Nine Springs Oil Co.	Bradley No. 1	Ab. 1939	3271′	Top Tca 875′; Tsq 2030′; Ke-Jf 2210′	Ke-Jf	
C 22	United Western Oil Co.	Bradley No. 1	Ab. 1939	4403′	Top Tca 1410′; Tsq 2530′; Ke-Jf 2800′	Ke-Jf	
C 23	Hub Oil Co.	La Laguna No. 1	Ab. 1944	5845′	Top Tca 1620′; Tsq 2635′; Tm 3375′; Ke-Jf 5520′	Ke-Jf	
C 24	General Petroleum Corp.	La Laguna No. 1	Ab. 1940	3099′	Top Tca 1860′; Tsq 3200′± Tm 3550′	Tm	
C 25	General Petroleum Corp.	Chamberlain No. 1	Ab. 1939	4310′	Top Tca 1150′±; Tsq 2125′; Tm 2800′; Ke-Jf 4180′	Ke-Jf	
C 26	Standard Oil Co.	La Laguna No. 2	Ab. 1925	3956′		?	
C 27	Standard Oil Co.	La Laguna No. 1	Ab. 1925	1300′		?	
C 28	L. G. Tannehill	McGillivray No. 1	Ab. 1930	4385′	Top Tsq 3040′	Tsq	
C 29	Carranza Oil Co.	Quati No. 1	Ab. 1925?	2954′			
C 30	Tidewater Assoc. Oil Co.	Quati No. 1	Ab. 1917	3515′	Top Tca 2304′?; Tsq 2360?	Tsq	Tar sand 2340-60′
C 31	Tidewater Assoc. Oil Co.	Quati No. 75	Ab.	4033′			
C 32	Tidewater Assoc. Oil Co.	Davis No. 1	Comp. 1942	6643′	Top Tsq 1460′; Tm 3200′ Ke or Jf 6509′	Ke-Jf	Discovery well—Zaca field I.P. 294 B/D 7° 33% emul. (incl. 37 bbls. distil.)
C 33	Tidewater Assoc. Oil Co.	Davis No. 35	Comp.	4810′			
C 34	Tidewater Assoc. Oil Co.	Davis No. 34	Comp.	4628′			
C 35	Tidewater Assoc. Oil Co.	Chamberlin No. 1	Comp. 1943	5794′	Top Tsq 1663′; Tm 3120′	Tm	I.P. 311 B/D 8° 29% cut (incl. 31 bbls. distil.)

Map No.	Operator	Well	Year Comp. or Aband.	Depth	Geology	Geol. at Bottom	Remarks
C 36	Tidewater Assoc. Oil Co.	Chamberlin No. 22	Comp. 1948	5340′			
C 37	Tidewater Assoc. Oil Co.	Chamberlin No. 31	Location				
C 38	Tidewater Assoc. Oil Co.	Chamberlin No. 51	Comp. 1948	6125′			I.P. 89 B/D 37%
C 39	Tidewater Assoc. Oil Co.	Luton No. 51	Comp. 1948	4387′			Plug. to 4159′ I.P. 180 B/D 0.2%
C 40	Tidewater Assoc. Oil Co.	Luton No. 71	Comp. 1947	5194′			I.P. 219 B/D net est., 8°
C 41	Tidewater Assoc. Oil Co.	Luton No. 93	Comp.	5314′			
C 42	Tidewater Assoc. Oil Co.	Luton No. 135	Comp. 1948	5301′			I.P. 141 B/D 8-10° 32% cut (incl. 110 bbls. distil.)
C 43	Standard Oil Co.	Fithian No. 1	Ab. 1918	4602′			

Point Conception Quadrangle

Map No.	Operator	Well	Year Comp. or Aband.	Depth	Geology	Geol. at Bottom	Remarks
D 1	Universal Cons. Co.	Conception No. 1	Ab. 1930	4992′	Top Tm 150′± Tr(?) 985′ Tv(?) 1035′; Ta 1110′; 1110 to 4992 undiff. Ta, Tg, Tsa sandstone & shale	Tg or Tsa	
D 2	Doheny-Pac. Pet. Co.	Conception No. 1	Ab. 1930	4986′			
D 3	Standard Oil Co.	Gerber No. 1	Ab. 1931	6820′	Top Tr 850′±; Tv 1715′; Ta 1917′; Tsa 3400±	Tsa?	
D 4	Monterey Expl. Co.	Hollister No. 1	Ab. 1933	3659′	Top Tr 2800′; Tv 3582′	Tv	
D 5	Western Gulf Oil Co.	Hollister No. 1	Ab. 1929	3597′	Top Tm 500′±; Tr 1800′; Tv 3088; Ts & Ta 3300′	Ta	Produced 25,000,000 cu. ft. gas per day
D 6	Western Gulf Oil Co.	Hollister No. 2	Ab. 1929	3200′	Top Tv 3094′	Tv	Produced 6,000,000 cu. ft. gas per day
D 7	Wilshire Oil Co.	Hollister No. 1	Ab. 1939	4658′	Top Tv 3371; Ta 3411′	Ta or Tg	Oil & gas shows below 4000 feet
D 8	Gaviota Oil Co.	Hollister No. 1	Ab. 1938	3215′	Top Tv 3126′	Tv	Produced 9,000,000 cu. ft. gas per day
D 9	Republic Pet. Co.	Hollister No. 1	Ab. 1940	3630′	Top Tm 800′; Tr 2278′; Tv 3507′	Tv	

Gaviota Quadrangle

Map No.	Operator	Well	Year Comp. or Aband.	Depth	Geology	Geol. at Bottom	Remarks
E 1	A. E. Tweedy	Tweedy Penn	Ab. 1939	2334′	Top Tv 2240′	Tv	
E 2	Calif.-American Oil Co.		Ab.	1600′			
E 3	Hamilton & Sherman	Rutherford No. 1	Ab. 1945	2275′	Top Tv 2073′	Tv	
E 4	Milbourn & Hamilton	Rutherford No. 1	Ab. 1940	1858′	Top Tv 1810′	Tv	
E 5	Shell Oil Co.	Rutherford No. 1	Ab. 1928	638′		Tr	Casing parted
E 6	Shell Oil Co.	Rutherford No. 1A	Ab. 1929	6148′	Top Tv 1478′; Ts 1845′; Tg-sa 4170′ Tsa? sh 5126′	Tg-sa	Produced gas, salt water
E 7	Shell Oil Co.	Rutherford No. 2	Ab. 1929	1887′	Top Tv 1478′; Ts 1848′	Ts	
E 8	Shell Oil Co.	Rutherford No. 3	Ab. 1930	2339′	Top Tv 1712′; fault @ 2052′; Top Tv 2334′	Tv	
E 9	Shell Oil Co.	Careaga 2-1	Ab. 1948	1763′	Top Tr 146′; Tv 1676′	Tv	
E 10	Shell Oil Co.	Careaga 2-2	Ab. 1948	4887′	Top Tv 2101′; Ts 2475′; Tg-sa 4585′	Tg-sa	
E 11	Graham & Loftus	Orella No. 1	Ab. 1928	1650′	Top Tv 1600′	Tv	
E 12	The Texas Co.	Careaga No. 1	Ab. 1937	1793′	Top Tv 1561′	Tv	
E 13	Rothschild Oil Co.	Orella No. 1	Comp. 1946	3119′	Top Tv 1535′; Ts 1830′	Ts	Discovery Orella gas field. Flowed 5,000,000 cu. ft. gas per day
E 14	Rothschild Oil Co.	Orella No. 2	Ab. 1947	3882′	Top Tv 1503′; Ts 1930′	Ts	
E 15	Rothschild Oil Co.	Orella No. 3	Comp. 1947	4326′	Top Tv 1710′; Ts 2040′	Ts	Gas well
E 16	Oakburn Drilling Co.	State No. 170-1	Ab.	1302′	Top Tv 1241	Tv	
E 17	Oakburn Drilling Co.	State No. 169-1	Ab. 1931	2821′	Top Tv 1286′; Ts 1618′	Ts	1000-1500 cu. ft. gas & fresh water
E 18	Indian Pet. Co.	State No. 174-1	Ab. 1930	1668′	Top Tv 1648′	Tv	gy sd
E 19	Litho Oil Co.	Rhode Island Est. No. 1	Ab. 1939	3060′	Top Tv 1768′; Ts 2160′	Ts	Faint shows oil & gas 1750-68
E 20	C. M. Morse	Rhode Island Est. No. 1	Ab.	536′		?	
E 21	Prairie Oil & Gas Co.	Canada del Corral No. 1	Ab. 1930	4383′	Top tr 900′; Tv 2770′; Ts 3230′	Ts	
E 22	General Pet. Corp.	Erburu No. 1	Comp. 1929	1446′	Top Tv 1270′	Tv	Discovery, Capitan field—I.P. 109 B/D 20.8 gr. 2.7%
E 23	General Pet. Corp.	Erburu No. 8	Comp. 1930	4071′	Top Tv 1234′; Ts 1650′; Tg-sa 4028′	Tg-sa	Discovery Sespe zones Oil sd 1200-1330′; 2240′-2350′; 2410-2525′
E 24	Shell Oil Co.	Covarrubias No. 1-35	Comp. 1944	4024′	Top Tv 1060′; Ts 1420′; Tg-sa 3720′	Tg-sa	Oil sd 1060′-1330′; 2100-2220′; fluid 1620 B/D 39.2, 1% 1200 MCF gas
E 25	Shell Oil Co.	Covarrubias No. 2-2	Comp. 1937	2993′	Top Tv 2000′; fault @ 2200′; Top Ts 2200′	Ts	Oil sands below 2200′ 35 B/D 50%
E 26	Shell Oil Co.	Covarrubias No. 2-4	Ab.	3242′			
E 27	The Texas Co.	Johnson No. 1	Ab. 1948	3750′			

Asphalt

Four deposits of asphalt in the form of tar-impregnated sands occur in the area mapped, one on the south coast and three in the Purisima Hills. None has been quarried.

Along the sea-cliff within 1½ miles west of Gaviota Beach are five exposures of chert pebble conglomerate and sand; and one exposure on the south face of a hill 2 miles west, in which the sand is well impregnated with asphalt. This conglomerate probably forms the base of the Sisquoc although some occurs in the upper Monterey. It attains a maximum exposed thickness of about 50 feet and dips about 45° S. Thin lenses of this conglomerate also crop out east of Cuarta Canyon and at Sacate Canyon.

In the eastern Purisima Hills is a large deposit of tar-soaked sand at the base of the Sisquoc on the west side of the canyon 1½ miles north of Jonata Park. This deposit consists of very fine sand heavily impregnated with asphalt. It is about 75 feet in maximum thickness and extends about a mile, dipping steeply north into a syncline. This tar sand grades laterally along the strike into oil shale.

Redrock Mountain in the central Purisima Hills is formed by a large deposit of tar-soaked sand. This consists of fine sand of the Careaga formation, is about 50 feet thick, and caps the mountain. The sand is well impregnated with asphalt. Two erosional remnants of this tar sand occur about 1 mile down the spur to the southwest. The tar sand of Redrock Mountain is underlain by highly bituminous shale of the lower Sisquoc which has locally been burned, causing it to become brilliant red and locally scoriaceous.

A small deposit of tar sand occurs at Lompoc oil field in Purisima Canyon. This consists of medium-grained Careaga sand impregnated with asphalt. It is about 25 feet thick and dips gently south. At the south end of Harris grade is exposed about 15 feet of basal Careaga (?) tar sand lying unconformably on Sisquoc diatomite.

Diatomite

The southern portion of the Santa Maria Basin is noteworthy for its extensive deposits of diatomite, or diatomaceous earth. This is all of marine origin, of upper Miocene and lower Pliocene age, and is confined largely to the Sisquoc formation, except for local interbeds in the upper Monterey shale. The diatomite deposits are developed in the Purisima Hills, Santa Ynez Valley, and in the northern foothills of the Santa Ynez Mountains south of Lompoc Valley. In the last-named area it is remarkably pure and makes up the largest known diatomite deposit of commercial value in the world, which contains the world's largest diatomite workings. Diatomite deposits of known and potential economic value are shown on the economic maps.

Types of Diatomite

The diatomite of the Sisquoc and Monterey formations is of three types: (1) pure thinly stratified; (2) impure coarsely stratified; and (3) impure massive. The pure thinly stratified diatomite is of commercial value and is marketed under the trade name "Celite," by Johns-Manville Products Corporation. The impure diatomites are of little or no commercial value.

The thinly stratified diatomite is soft, very light weight, porous, and made up of laminae averaging about $\frac{1}{32}$ of an inch. It is coherent, but tends to fracture along bedding planes, and is nearly pure white when dry; but below the surface it is cream-colored and contains 50 percent moisture. It is of such high porosity that it will absorb nearly 75 percent water when saturated. The material is made up almost entirely of well-preserved siliceous tests of diatoms. These comprise more than 200 species, but in general there are two types—disc-shaped diatoms, and filiform or needle-shaped diatoms. These occur in varying ratios in different strata, but the disc types generally predominate. In addition to diatoms, there are subordinate siliceous remains of animal life such as radiolaria, silicoflagellates, and sponge spicules. The thinly stratified diatomite contains very minor impurities such as flakes of volcanic ash and particles of clay, quartz, or amorphous silica.

The impure coarsely stratified diatomite consists of the above type with as much as 10 percent admixture of clayey material. This diatomite differs from the thinly stratified type; it is heavier and less porous, and is cream colored when dry, and light brown when moist. The diatoms are generally more broken. This type is rejected as waste.

The impure massive diatomite is also cream colored and contains an admixture of clayey material ranging from a fraction of 1 percent to 50 percent, beyond which it grades into diatomaceous claystone. It is typically massive and breaks with conchoidal fracture. The diatoms are generally broken and poorly preserved, and the material is somewhat harder and less porous than the other two types.

Deposits South of Lompoc Valley

The hills south of Lompoc Valley and the western Santa Rita Hills contain several deposits of high-grade commercial diatomite covering an area of about 17 square miles. This diatomite is of upper Miocene age and comprises the lower 1000 feet of the Sisquoc formation (assigned to Monterey formation by Arnold and Anderson,[56] and by Mulryan [57]), and minor amounts are locally interbedded in the siliceous shale of the upper Monterey formation. The upper Sisquoc in this area is of the impure massive type and consequently of no economic value. The high-grade lower Sisquoc diatomite crops out along the northern slopes of the Lompoc and Santa Rita Hills, where it dips northward under Lompoc Valley. Farther south in these hills the diatomite is largely eroded away, but is preserved in several basin-like synclines where it is quarried.

The lower Sisquoc diatomite consists of alternating layers of the pure thinly stratified variety, and the impure coarsely stratified variety, as previously described. Determination of the quality of the diatomite requires much sampling and microscopic examination. Chemical tests are required to determine the amount and kind of impurities. As the pure diatomite occurs in certain strata, selective quarrying of these layers is required. The lower Sisquoc diatomite is remarkably free of other rock types. Layers of opaline chert seldom occur and these in beds only a few inches thick. In some places the chert occurs as nodules or nodular layers. Thin layers of volcanic ash are locally present. In the Santa Rita Hills the base of the lower Sisquoc diatomite is locally marked by a layer of phosphatic pebbles or pellets, or by sand. At some places about a foot of lime-

[56] Op. cit.
[57] Mulryan, H., Geology, mining, and processing of diatomite at Lompoc, Santa Barbara County, California: California Div. Mines Rept. 32, pp. 133-166, 1936.

stone occurs near the base, but in most places the lower Sisquoc diatomite lies conformably on Monterey cherty shale, or grades down into it through about 50 feet of beds.

Diatomite of the upper Monterey is similar to that of the lower Sisquoc, except that it is interbedded with opaline and cherty shales. Much of the diatomite is of high quality, but it seldom occurs in pure beds more than 50 feet thick. The diatomites of the upper Monterey are local phases of opaline cherty shale, into which they grade laterally. They occur in the vicinity of Salsipuedes and San Miguelito Canyons, and also in Espada Canyon.

Deposits of Purisima Hills and Santa Ynez Valley

The Sisquoc formation of the Purisima Hills is composed largely of impure, coarsely stratified and massive diatomite, and is therefore of little or no commercial value. However, in the eastern Purisima Hills west of Zaca Creek, there is a small deposit of high-grade diatomite, consisting of about 500 feet of thinly stratified diatomite in the uppermost Monterey formation below the basal Sisquoc tar sand. This diatomite occurs in a west-plunging syncline 1 mile north of Jonata Park, and also on the north flank of the adjacent anticline to the north. The lower Sisquoc also contains some thinly stratified diatomite 1 mile west of Jonata Park. None of these deposits have been worked.

In Santa Ynez Valley in the vicinity of Solvang is a small deposit of pure thinly stratified diatomite occurring in the lower Sisquoc formation. About 500 feet of diatomite is exposed and occurs in a sharp anticline and syncline. The deposit was quarried and mined 1 mile northwest of Solvang.

On the north flank of the anticline east of Santa Ynez are several outcrops of stratified white diatomite about 1000 feet thick in the lower Sisquoc formation. Some of this is of possible commercial grade. It is largely concealed by terrace deposits.

Uses of Diatomite

To quote from Mulryan [58]:

> "Briefly summarizing, the principal uses of Celite Diatomite Products are: In insulation at comparatively high temperatures, also low temperatures, building insulation, and filtration of all types of liquids from the most viscous to the least viscous; as admixtures and mineral fillers where a chemically inert light-weight mineral is required, as a mild abrasive in polishes, and a filler in paints."

Diatomite Quarries

Johns-Manville Quarries. For a detailed description of the Johns-Manville quarries, the reader is referred to Mulryan's [59] report in which the geology of the diatomite deposit and the mining and processing operations by the Johns-Manville Products Corporation are described. These are summarized in the following abstract [60]:

> "The largest and purest known deposit of diatomite is being actively mined and processed three and one-half miles south of Lompoc, Santa Barbara County, California, by the Johns-Manville Corporation.
>
> "The workings cover 4000 acres, the depth of economically recoverable diatomite being 1000 feet.

[58] Op. cit., p. 164.
[59] Op. cit., pp. 133-136.
[60] Mulryan, H., op. cit., pp. 133-134.

"These marine beds assigned to the Monterey formation, upper Miocene are generally soft, white, extremely porous, light weight, and of remarkable uniformity and purity.

"The diatomite is quarried on the surface by gasoline and diesel-powered shovels, and loaded into trucks which haul the material to vertical storage shafts sunk in the diatomite. The diatomite is drawn off at the bottoms of the holes into cars and hauled underground by electric trolley locomotive to the primary crushing plant.

"The crushed crude is conveyed to mill bins and processed. Powders for filtration, admixtures, mineral fillers, and insulation purposes are produced in the milling systems.

"Insulation brick are sawed directly in the quarries or produced from aggregates and calcined in a tunnel or beehive kiln.

"The company maintains a complete machine shop, garage, electric and carpenter shop, camp for employees, hospital, and a plant development department at the deposit. A research staff is established at Manville, New Jersey."

Concerning the diatomite deposit, Mulryan [61] makes the following statement:

"The company owns or controls an area comprising 4000 acres in the main deposit. The diatomite contained therein is remarkable because of its high degree of purity in this huge deposit. It is generally accepted as the largest and purest known deposit in the world. Its great thickness, more than 1000 feet, and its undisturbed condition, with the added benefit of sufficient relief to permit easy mining conditions, certainly place the deposit in a unique position."

The writer is not in complete agreement with Mulryan concerning the geology of the diatomite deposit. Mulryan follows Arnold and Anderson [62] in assigning the diatomite to the Monterey formation, but the writer restricts only the diatomite interbedded with siliceous shales to the Monterey, and assigns the overlying 1000 feet of homogeneous diatomite to the Sisquoc formation, on the basis of regional mapping and for reasons stated under *Stratigraphy.*

Mulryan [63] states that the eastward-trending syncline containing the diatomite deposit of Johns-Manville Products Corporation is a down-faulted block, bounded on the northeast by a major cross-fault following Salsipuedes Creek, and on the southwest by another in San Miguel Canyon. The writer has found no conclusive evidence of such faults—at least not on a major scale—and believes that the synclinal structure containing the diatomite rises both east and west from the Johns-Manville property, forming a structural basin as indicated on the geologic map of the Lompoc quadrangle.

Dicalite Quarries. About 7 miles southeast of Lompoc is a large diatomite deposit on the portion of Rancho San Julian owned by W. C. H. Dibblee. This deposit was leased in 1942 to the Dicalite Company which, since 1945, has been the Dicalite Division of Great Lakes Carbon Corporation. The diatomite of this deposit is of high commercial value similar to that of the Johns-Manville quarries; it covers some 1,500 acres and contains an estimated 166,000,000 cubic yards of diatomite.

The diatomite of the Dicalite quarries is assigned to the lower Sisquoc formation and is the same in lithology and quality as that of the Johns-Manville quarries; it lies with sharp, but conformable, contact on Monterey cherty shale. The diatomite occurs in a structural basin,

[61] Op. cit., p. 141.
[62] Op. cit.
[63] Op. cit., p. 139.

similar to that of the Johns-Manville deposit, composed of three synclines separated by two anticlines. These folds trend about N. 85° W. and extend about 2 miles; dips vary from flat on the axes of the folds to 50° on the flanks. The north syncline is the largest and contains diatomite to an estimated maximum depth of 700 feet. The middle syncline contains diatomite to about 500 feet maximum depth, and the south syncline to about 250 feet depth.

The diatomite of the Dicalite quarries contains occasional thin layers of volcanic ash as at the Johns-Manville quarries. Some diatomite layers carry many dark brown phosphatic lenticular concretions 1 inch to 2 inches in diameter and half an inch thick.

In 1943 the diatomite deposit was quarried by the Dicalite Company, and in 1947 by Dicalite Division of Great Lakes Carbon Corporation. The method used was surface quarrying and hauling by truck. Operations at the deposit are still in the development stage, there being no underground workings nor processing plant. The deposit has been prospected by trenching and scraping of ridges by bulldozer, and by vertical holes 30 inches in diameter and about 50 feet deep.

Quarrying operations have been confined to the north syncline. Only layers containing thinly stratified pure diatomite are quarried; associated impure diatomite is dumped as overburden. In 1943 the high-grade diatomite was quarried by power shovel, but during 1947 it was quarried by carry-all. The quarried material is loaded onto dump trucks which haul it to stock piles located adjacent to the main surfaced road. From the stock piles the diatomite is moved by dragline to a loading chute where it is loaded onto truck and trailer, covered by tarpaulin, and hauled about 150 miles to the Dicalite processing plant located at Walteria in the Palos Verdes Hills east of Palos Verdes, California.

Diatomite Quarry in La Salle Canyon. Five miles southwest of Lompoc on the east side of La Salle Canyon, lower Sisquoc diatomite dips steeply north. The plant is idle.

Diatomite Quarry Near Solvang. One and a half miles northwest of Solvang lower Sisquoc diatomite dips generally south, but a small fold is exposed. The plant is idle.

Limestone

Deposits of limestone occur at the base of the Monterey shale in the northwestern Santa Ynez Mountains near Lompoc. Limestone crops out on both sides of El Jaro Canyon below the juncture of Los Amoles Creek. The limestone here is white, but weathers gray on the surface; it is dense, massive, and hard, but generally much fractured, breaking into irregular pieces. The upper portion is limestone but the lower portion becomes calcareous tuffaceous sandstone with local occurrences of conglomerate at the base. Total maximum thickness aggregates about 150 feet; the pure limestone has a maximum thickness of about 70 feet. Locally several thin lenses of limestone occur in the overlying shales of the Monterey. The structure of the limestone and overlying shales here is that of gently undulating folds. The limestone forms many landslides, especially where it is underlain by soft formations.

Between San Pascual and La Salle Canyons southwest of Lompoc is a limestone bed of about 100 feet maximum thickness which dips steeply north and is exposed for a distance of more than 2 miles, between

Monterey shale above and Tranquillon agglomerate below. The limestone is similar to that of El Jaro Canyon, consisting of pure limestone grading downward into calcareous sandstone.

The Miocene limestone of the northwestern Santa Ynez Mountains has not been worked for cement, but at El Jaro Creek, 7 miles southeast of Lompoc, it has been quarried and crushed for road gravel.

Southwest of Solvang the basal Monterey limestone is exposed along the south bank of the Santa Ynez River for a distance of about three-quarters of a mile, where it dips steeply north. The limestone here is impure and is made up largely of calcareous algae. It is quarried for road material.

The Sierra Blanca limestone exposed in Nojoqui Canyon and at several other localities in the Santa Ynez Mountains, is sandy and contains calcareous algae. It was quarried at Nojoqui Canyon for road material.

Bentonite

Thin beds of bentonite are locally developed at the base of the Monterey shale or in the Tranquillon formation at various places in the Santa Ynez Mountains. Several exposures occur between Gaviota and Cojo Canyon on the south flank; it is also exposed in Gijote Canyon and Llanitos Canyon. It is probably rhyolitic, as it is associated with rhyolite tuff in Cojo Canyon. It has not been quarried.

Flagstone

Slab-rock suitable for flagstone has been quarried at two locations in the western Santa Ynez Mountains. One of these is at the Golondrina Dairy of Rancho San Julian, on the highway 6 miles west of Las Cruces. The rock was hand-quarried in 1929 by A. Dibblee Poett and sold to private individuals. The rock-slabs occur in shale of the upper part of the Sacate formation (Eocene) which here dips steeply north on a north-facing hillside. The slabs average about 3 inches thick, are unusually large, and consist of extremely hard, coherent, fine-grained sandstone. They make excellent flagstones for garden-paths, steps, or stone floors.

The flagstones are confined to the upper shale member of the Sacate formation, and are well developed along the strike some 2 miles to the west on the divide between San Julian and Los Amoles Valleys, where they dip gently northeast.

Flagstones were quarried at Tajiguas prior to 1942. These occur as large slabs of hard, coherent calcareous and siliceous shale in the lower Monterey shale, ranging up to a foot in thickness. The formation here dips about 20° S., and is almost a dip-slope on a south-sloping hillside.

Road Gravel

Dibblee Quarry. The Dibblee quarry is a large quarry on the north side of El Jaro Canyon 7 miles southeast of Lompoc. It is on the W. C. H. Dibblee property of Rancho San Julian and was worked occasionally from 1928 to 1944 by the Santa Barbara County Road Department. The rock quarried is basal limestone of the Monterey shale, which here dips north into the hill. The limestone here is about 40 feet thick, grading upward into brittle cherty shales. About 15 feet of conglomerate occurs at the base of the limestone. The limestone and overlying shale are much fractured. Quarrying is done by blasting and power shovel, and the rock is crushed into gravel of various sizes. It was used for surfacing the Lompoc-Las Cruces road and other roads in the Lompoc area.

Alisal Quarry. The Alisal quarry is located on the south side of Santa Ynez River 1 mile south of Solvang. The quarry is in basal limestone of the Monterey shale, which here dips very steeply north and forms the south bank of the Santa Ynez River. The rock consists largely of very hard light-gray algal limestone, about 50 feet thick. The basal portion consists of calcareous and tuffaceous pebbly fossiliferous hard sandstone.

The quarry was operated at various times by the county between 1928 and 1941, by blasting and power shovel. The rock was crushed into gravel of various sizes and used in surfacing roads in the Santa Ynez Valley.

Callejon Quarry. The Callejon quarry is near Callejon Dairy of Rancho San Julian, on the Lompoc-Las Cruces road, 4 miles west of Las Cruces. The rock was first quarried in 1928 by the Santa Barbara County Road Department, and again in 1947-48 by the California Division of Highways through N. W. Ball and Son, contractor. The quarry is in Vaqueros conglomerate and sandstone which here is on end or slightly overturned northward. The formation is about 300 feet thick. The rock consists of basal pebble conglomerate with a brown clayey sandstone matrix, grading upward into pebbly sandstone. The formation is soft and easily quarried by bulldozer and power shovel. About 67,000 tons were removed in 1947-48 and the material was used in resurfacing the highway between Las Cruces and San Julian ranch-house gate.

Monterey Shale Gravel Quarries. Loose talus gravel of Monterey cherty shale has been quarried at many places in the vicinity of El Jaro Creek for use as road gravel. One of these is on the east side of El Jaro Canyon 7½ miles southeast of Lompoc; another in Los Amoles Canyon half a mile above the juncture with El Jaro Creek; one at El Chorro Ranch, 9 miles southeast of Lompoc; and one about a mile up Yridises Canyon.

All of these were quarried in 1928-30 by the Santa Barbara County Road Department for use on the Lompoc-Las Cruces highway which was being rebuilt at that time. Quarrying was done by steam shovel, and the loose shale was loaded directly into trucks without treatment.

Buell Flat Rock Quarry. Just west of Solvang, Recent stream gravel of the Santa Ynez River bed is quarried by the Buell Flat Rock Company of Solvang, and is used mainly as road material. The gravel is fairly clean and is quarried by power shovel, and sorted by screening into various sizes from 2-inch to pea gravel.

River Quarry Near Santa Rosa Park. In the Santa Ynez River bed at the mouth of Drum Canyon near Santa Rosa County Park is a gravel quarry operated by Cox and Chilson of Lompoc. The gravel is similar to that of Buell Flat quarry and operations are the same.

Manganese Ore

A small deposit of manganese ore (pyrolusite or psilomelane) occurs in the Franciscan formation of the San Rafael Mountains 7 miles northeast of Los Olivos. The ore occurs as a somewhat lenticular mass roughly 20 feet thick in dark maroon ferruginous chert, dipping steeply north. Workings consist of an open shaft about 6 feet square and about 20 feet deep. The prospect may contain a lower level but was not entered.

7—13966

This and another manganese prospect of little apparent value were briefly described by F. S. Hudson as Santa Barbara County manganese deposit no. 2, La Laguna Rancho, in a recent bulletin by Trask and others.[64]

Water

Springs. In Santa Ynez Valley, immediately west of Santa Ynez, a large artesian spring issues from terrestrial gravels. The volume is sufficient for irrigation and was used for this purpose on the lands of Mission Santa Inez by the Franciscan Fathers who first settled in Santa Ynez Valley.

The Santa Ynez spring is believed to issue from the saddle between the east end of the Purisima anticlinal uplift and the large anticline rising eastward from Santa Ynez. This gravel-filled gap between these two uplifts apparently acts as the outlet for the underground water of practically the entire drainage basin of upper Santa Ynez Valley, and at this outlet the water gathers in such large volume as to reach the surface.

In the San Rafael Mountains numerous springs issue from serpentine and landslide masses of the Franciscan formation. In the Santa Ynez Mountains are many springs, which issue mainly from the following formations in order of abundance: (1) Vaqueros pebble conglomerate; (2) Sespe conglomerate (Nojoqui-Alisal area); (3) Tranquillon volcanics and Monterey basal limestone; (4) Matilija sandstone; (5) sandstones of other formations; (6) Monterey cherty shale; and (7) clay shales. In general, springs are most abundant in these formations where the geologic structure is complex and where there is much landsliding.

One of several hot springs which issue from the Santa Ynez fault occurs within the mapped area just south of Las Cruces. This spring is apparently of deep-seated origin along the fault. The water has a temperature of about 100° F., and carries some sulfur.

Few springs occur in the Purisima and San Rafael foothills.

Ground Water. A detailed investigation of the ground-water resources of Santa Ynez and Lompoc Valleys has recently been completed by J. E. Upson and others.[65] In Lompoc Plain and throughout the flood-plain of the Santa Ynez River, wells drilled into the basal gravel member of the alluvium produce water in large amounts sufficient for irrigation. The Careaga sand which underlies this gravel in Lompoc Plain is likewise water-bearing, but the loose sand runs into the wells and causes trouble. Irrigation water is also produced from wells drilled into alluvial gravels of stream valleys traversing the San Rafael foothills and upper Santa Ynez Valley. Alluvial sands and gravels of Los Alamos Valley also yield large amounts of water.

The alluvium of stream valleys within the Santa Ynez Mountains and Purisima Hills generally contains too much loam and too little gravel to produce enough water for irrigation, but generally yields enough for stock or domestic purposes.

Wells drilled into gravels of the Paso Robles formation yield small amounts of water. The Careaga sand yields fair amounts, but generally causes sanding trouble. Diatomite, shale, and siltstone formations do not yield water unless fractured. Brittle, fractured Monterey cherty shale

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[64] Trask, Parker D., and others, Geologic description of the manganese deposits of California: California Div. Mines Bull. 125, p. 173, 1943.

[65] Op. cit., 1947.

will generally yield water—sometimes in fair quantities. Sandstone generally yields small amounts, but when the formation is tight, the water comes mainly from fractures or joints rather than from the sandstone itself. Under favorable structural and topographic conditions fair amounts of water can be obtained from sandstones. J. S. Hollister has drilled several near-horizontal wells into steeply dipping Matilija sandstone on the Hollister and San Julian ranches and has obtained up to 120 gallons per minute of excellent water.

Water from some formations locally contains large amounts of mineral salts. This is especially true of waters from serpentine, or from the Sespe, Vaqueros, and Monterey formations, which locally contain hydrogen sulfide, sulfate, and carbonates of calcium, magnesium, iron, sodium, and potassium.

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INDEX

A

B

C

D

Q

R

S